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INTERNATIONAL YEAR OF FORESTS • 2011

Proceedings of
International Symposium

International Forest Fire Symposium

Commemorating the International Year of Forests 2011

Date

June 7-8, 2011

Place

Sol Beach, Gangwon-do, Republic of Korea

Hosted by

국립산림과학원 KOREA FOREST RESEARCH INSTITUTE

Supported by

산림청 KOREA FOREST SERVICE

GANGWON PROVINCE

KNU 강원대학교 KANGWON NATIONAL UNIVERSITY

International Forest Fire Symposium
Commemorating the International Year of Forests 2011

Background

- Discussion on reducing forest fire damage
- Public relations for the progression in the prevention and suppression
- Strategies since 2000's mega fires in Republic of Korea
- Reviews on situation of ecosystem due to restoring activity in burned area
- Exchanging information on preventing mega fires in the world

Subjects of Symposium

- The progression in the strategies about fire prevention and suppression since 2000's mega fires in Republic of Korea
  - Improvement of the fire prevention and suppression techniques by IT
  - Characteristics of forest fires and countermeasures in each country
  - Strategies for reducing the forest fire damages
- The stabilization of ecosystem and restoring progress for 10-year after mega fire at Korea's East Coast in 2000

Schedule

- Dates: June 7~8, 2011
- Venue: Sol Beach, Yangyang-gun, Gangwon-do, Republic of Korea
- Program Schedule

Dates	Program	Location	Place
7 June	Oral Presentation	Sol Bearch resort Conference room	Yangyang-gun, Gangwon-do
8 June	Poster Session & Awarding		

PROGRAMME

• Oral Presentation, June 7, 2011 (Tuesday)

Time	Activity/Seminar
09:00~10:00	**Participants Registration**
10:00~10:10	**Opening address** Dr. Gil Bon Koo (Director General, KFRI, Korea)
10:10~10:35	**Congratulatory address I** Dr. Don Koo Lee (Minister, KFS, Korea) **Congratulatory address II** Mr. Moonsoon Choi (Governor, Gangwon-do) **Congratulatory address III** Prof. Johann G. Goldammer (Chair UN_ISDR/GFMC)
10:35~10:45	**Welcome address** Dr. Sun Do Choi (Vice President of Kangwon Univ. Korea)
10:45~10:50	**Photo time**
10:50~11:00	**Coffee Break**
11:00~11:20	**Keynote Speech I** **International protocols and agreements on cooperation in wildland fire management: needs, current status, and the way ahead in the asian region and at global level** Prof. Johann G. Goldammer (Chair UN_ISDR/GFMC)
11:20~11:35	**Forest fires and management in China** Dr. Xiaorui Tian (CAF, China)
11:35~11:50	**Forest fires suppression strategy and management in Korea** Mr. Hyunbok Lee (KFS, Korea)
11:50~12:05	**The report of forest fire organization, system and skill in Korea** Prof. Siyoung Lee (Kangwon Univ. Korea)
12:05~12:20	**WRF-fire simulation of the 2005 Yangyang, Gangwon province forest fire** Dr. Sangok Han (NIMR, Korea)
12:20~14:00	**Lunch**

Time	Activity/Seminar
14:00~14:15	**Soap-based firefighting foam for forest fire, current forest fire situation in Japan** Prof. Kazuya Uezu (Kitakyushu Univ. Japan)
14:15~14:30	**Spatial pattern of human caused forest fire in Korea** Prof. Wookyun Lee (Korea Univ. Korea)
14:30~14:45	**Indonesian forest fires moratorium and greenhouse gas emission reduction** Prof. Bambang Saharjo (BA Univ. Indonesia)
14:45~15:05	**Keynote Speech II** **Climate change impacts on forest fire characteristics and restoration strategy in Korea** Dr. Myungbo Lee (KFRI, Korea)
15:05~15:20	**Effects of disturbance intensity on arthropod communities in burned pine forests in Korea** Dr. Taesung Kwon (KFRI, Korea)
15:20~15:30	**Coffee Break**
15:30~15:45	**Impacts of forest fires on ecosystems functioning including biodiversity and climate change: a perspective from Hindu-Kush Himalayan (HKH) region** Mr. Sundar P. Sharma (MWR, Nepal)
15:45~16:00	**Assessment of the crown fire hazard of *Pinus densiflora* based on the crown fuel characteristics in Korea** Prof. Youngjin Lee (Kongju Univ. Korea)
16:00~16:15	**Bush fire management and cooperation** Dr. Jinjoo Jae (NEMA, Korea)
16:15~16:30	**The status of forest fires and management in Morgolia** Dr. Ganbaatar Jamiyansuren (Fire Department Agency(NEMA), Mongolia)
16:30~16:45	**Projection of climate change over East Asia based on global downscaling with high resolution AGCM** Prof. Jaiho Oh (Bukyung Univ. Korea)
16:45~17:00	**Vegetation regeneration and soil erosion for ten years following forest fires in Korea** Prof. Yeonsook Jung (Kangwon Univ. Korea)
17:00~17:30	**Question and Discussion** Dr. Kyongha Kim (KFRI, Korea)

• Poster Session, June 8, 2011(Wednesday)

Time	Activity/Seminar
09:00~09:30	**Attaching Posters** (June 7, 2011)
09:00~11:30	**Poster Presentation & Appraisal**
11:30~11:50	**Awarding of Poster Presentation** 1st : 1 Poster 2nd :1 Poster 3rd : 1 Poster
11:50~13:00	**Lunch**

• Exhibition

➢ Forest Fire Management and Suppression System

- Forest Fire Danger Rating System
- Device for Measuring Fire Weather
- Forest Fire Chemical
- Forest Fire Management System using Smartphone
- Korean Fire Pump
- MOLMOS : Forest fire and vegetation change detection program based on MODIS images

CONTENTS

OPENING SESSION

OPENING ADDRESS

I would like to sincerely welcome all distinguished participants for attending the International Forest Fire Symposium in the 「International Year of Forests 2011」 designated by United Nations in the acknowledgement of the importance of forests as the solution to overcome environmental crisis such as climate change.

Especially, I would like to acknowledge Dr. Johann G. Goldammer, chair of the Global Fire Monitoring Center (GFMC) under the UN International Strategy for Disaster Reduction (UNISDR), Dr. Tian Xiaorui, a researcher at the Chinese Academy of Forestry, Dr. Bambang Hero Saharjo, a professor at Bogor Agriculture University in Indonesia, Sundar P. Sharma, the representative of South Asian Networks, Kazuya Uezu, a professor at the Department of International Environmental Engineering, the University of Kitakyushu, and Ganbaatar Jamiyansuren, the senior officer at the National Emergency Management Agency in Mongolia.

Also, I want to thank the presenters, professors who will serve as the chairmen and participate in the discussion session for today's symposium, who are, Dr. Gyuho Lim, a professor at Seoul National University, Dr. Siyoung Lee, Dr. Jaeseon Yi, Dr. Yeonsook Jung, professors at Kangwon National University, Dr. Youngjin Lee, a professor at Kongju National University, Dr. Jaeho Oh, a professor at Pukyong University, Dr. Woogyun Lee, a professor at Korea University, Dr. Sangok Han of the National Institute of Meteorological Reserach, and Dr. Jinjoo Jae of the National Emergency Management Agency.

There have been several major forest fires of unprecedented size, that have recently broken out from place to place due to environmental issues, such as climate change. Forest fires are no longer an issue limited to only one country, rather they have become a global issue. From the tropics to Far-East Asia, ecosystems are becoming more vulnerable to forest fires. Large-scale forest fires have become a reality as well.

The international cooperation, which shares expertise experiences, and knowledge from other countries, as well as resources for extinguishing fires is urgently needed in order to deal with such forest fires effectively. The Fifth International Wildland Fire Conference(IWFC), held last May in South Africa, brought about regional agreement through bilateral and multilateral cooperation regarding international cooperation in the forest fire control sector. Additionally, the Fifth IWFC adopted a written agreement on cross-border cooperation at the worldwide level.

I am confident that today's the International Forest Fire Symposium and tomorrow's the International Conference of the Pan-Asia Wildland Fire Network are going to contribute to develop improved technology and find the most effective international cooperation. So, this will ultimately contribute to the wise use of forest fires.

The Korea Forest Research Institute (KFRI) is fulfilling its duties and fully committed to joint action towards forest fires occuring in Asia as the chair of the Reigonal North East Asia Forest Fire Network and Pan-Asia Wildland Fire Network as well as one of members of Global Wildland Fire Network.

Last but not least, I would like to acknowledge everyone's efforts for preparing the symposium with deep gratitude, especially to Mr. Moon Soon Choi, the governor of Kangwon Province, Dr. Sun Do Choi, the vice president of Kangwon National University, and Dr. Don Koo Lee, the minister of Korea Forest Service for their greatly spared supports.

I, once again, hope the symposium to be held most successfully, and extend many thanks to all distinguished guests for your commitment and interest in forest fire control.

Gil Bon Koo
Director General
Korea Forest Research Institute

CONGRATULATORY ADDRESS

I would like to offer my congratulations on the opening of the International Forest Fire Symposium to discuss effective ways for improving extinguishment technology, the forest ecosystem restoration technology, and international cooperation on large-scale forest fire. I believe it is very meaningful to hold the Symposium here in Yangyang, on the east coast of Korea where major forest fires broke out in 2000 and 2005.

The global change resulting from climate change, population growth, and land use change makes the world more vulnerable to forest fire and the frequency as well as the intensity has become increasingly serious over the past decades. For the resolution of these issues, establishment of integrated management strategy on forest fire, local community-based development and adaptation of forest fire management policy, and practical actions of international cooperation have become essential at this juncture.

Beginning with its response to a series of forest fires on the east coast of Korea in 2000, the Korea Forest Service as the government body in charge of forest fire has notably developed the whole process of forest fire prevention, extinguishment and restoration. The Korea Forest Service is affectively achieving the objectives of “early fire detection and rapid initial attack” through various measures, in particular by adopting cutting-edge information technologies to the field of forest fire management.

Additionally, the Korea Forest Service is providing training and education on forest fire control and the resources of extinguishment through bilateral and multilateral international cooperation in the forestry sector. The Korea Forest Service is fulfilling its duties as a major partner of international community also by hosting the sixth International Wildland Fire Conference (IWFC) in 2015, the largest international conference on forest fire.

The International Symposium on Forest Fire Control and the International Conference of the Pan-Asia Wildland Fire Network to be held tomorrow are going to be a solid platform for the successful meeting of the sixth International Wildland Fire Conference (IWFC). I hope strategies and technologies of forest fire management of every country and international organizations could be shared and ways of enhancing these technologies could be discussed, thereby contributing to forging effective countermeasures on worsening wildland fires.

And last but not least, I would like to express my gratitude to everyone who has been greatly supportive to bringing about this Symposium and would like to extend special thanks to Dr. Johann Goldammer, the chair of the Global Fire Monitoring Center (GFMC), many other distinguished guests from abroad, and Mr. Moon Soon Choi, Governor of Kangwon Province, Dr. Sun Do Choi, the vice president of Kangwon National University. I hope the Symposium builds up very successful and fruitful outcomes.

Don Koo Lee
Minister
Korea Forest Service

CONGRATULATORY ADDRESS

Excellencies,
Mr. Governor Moonsoon CHOI of Gangwon Province, Republic of Korea,
Minister Dr. Donkoo LEE, Head of the Korea Forest Service
Dr. Gilbon KOO, Director General of the Korea Forest Research Institute
Dr. Sundo CHOI, Vice President of Gangwon University

Let me take the opportunity of the opening of the "International Forest Fire Symposium Commemorating the International Year of Forests 2011" and the Second Pan-Asia & 7th North-East Asia Wildland Fire Network Meeting to reflect on the current situation of forest fires in the Asian Region and globally.

In today's conference forest fire specialists from Korea and neighboring countries of Asia are coming together to exchange recent experiences and views on fires affecting ecosystems throughout the region. At the Global Fire Monitoring Center, which is based in Germany, we are monitoring fires in the region regularly using satellite imageries. What we can see from space are the high-temperature signals indicating active fires. We can see the spread of smoke plumes in countries, and often crossing borders of countries and spreading thousands of kilometers. And we can see the "black scars" in the landscapes of Asia that are indicating the area burned in the different ecoregions.

This spring we have monitored fires all over the region. Major vegetation fires have been detected burning in Japan, on Kyushu Island on 13 March 2011, two days after the earthquake and tsunami hit the country. These fires were probably ignited by the many structural fires that started during the earthquake and spread to surrounding lands. At this time, however, the attention was given to save the lives of people affected by the disaster and to control the failure of the Fukushima Daiichi Nuclear Power Plant.

During the same week extensive wildfires were monitored in the highlands of Nepal, including fires burning in the Annapurna Conservation Area. You will hear more about the fire situation by the contribution of Mr. Sundar Sharma from Nepal and the Regional South Asia wildland Fire Network during this conference and the regional network meeting.

One month later extensive fires burning in the North of the Korean peninsular were depicted by satellites, indicating widespread agricultural burning activities producing smoke plumes that reached Japan.

In neighboring Southeast Asia the amount of fires set for conversion of native vegetation to other land use decreased as compared to earlier years. By monitoring not only the active fires in Southeast Asia but also the political environment we could see that leaders of the ASEAN member states did their best to meet the objectives of the regional ASEAN Agreement on Transboundary Haze Pollution and to reduce illegal burning activities throughout the region. You will hear more about recent developments by the representative of Indonesia, Professor Bambang Hero Saharjo from Bogor Agricultural University.

In the middle of May 2011 extensive wildfires started to affect the Central-Northern Asian region, in Yakutia, Russian Federation. The daily progress of wildfires affecting more than 100,000 hectares of forests could be seen from space until clouds and rainfall moved in towards the end of May and obscured the view from space.

In Europe, where the Global Fire Monitoring Center is located, we are experiencing an extreme drought. It looks like 2011 will become one of the driest years since long time – possibly a consequence of regional climate change. Many western European countries like the United Kingdom, Ireland, The Netherlands and Belgium experienced large wildfires – phenomena that are usually uncommon in these countries. The same happened in the United States of America where wildfires burning in dry grasslands, agricultural lands and forests caused major economic and humanitarian problems during the recent weeks.

Wildland fire specialists from throughout the world discussed the current and probable future situation four weeks ago at the 5th International Wildland Fire Conference in South Africa. The International Wildland Fire Conferences are taking place every four years and provide a major platform and forum of the international community of wildland fire specialists globally, especially those who are organize in the Global Wildland fire Network.

In an opening statement conveyed by the Secretary General of the United Nations,Mr. Ban Ki-moon, he encouraged the participants of the conference to identify real solutions that will help communities and nations to better handle the adverse impacts of fires and to build safer, more sustainable societies for all.

In the closing statement of the conference the Vice President of the Korean Forest Service, Mr. Yougho Ha, announced that the Republic of Korea with host the 6th International Wildland Fire Conference in 2015. With this Korea has taken over the torch to bring the spirit of global cooperation of wildland fire scientists, managers and policy makers to Asia.

I would like to congratulate the Republic of Korea, notably the Korea Forest Service and the Korea Forest Research Institute, to become host of the next global wildland fire conference. During this meeting and forthcoming consultations with the International Liaison Committee of the International Wildland Fire Conferences, as well as the Pan-Asia Wildland fire Network meetings this week and in 2013, the Republic of Korea will be a major contributor towards building global partnerships in fire management.

May I congratulate you, Mr. Governor Moonsoon CHOI, and Minister Dr. Donkoo LEE, as well as Dr. Gilbon KOO and Dr. Sundo CHOI, and the dedicated staff of the Department of Forest Conservation of the Korea Forest Research Institute, to host this conference and network meeting. I wish all of us a productive work atmosphere and a good spirit of international collaboration

Johann Georg Goldammer
Chairperson
Global Fire Monitoring Center (GFMC)

WELCOME ADDRESS

It is a great pleasure to host the International Forest Fire Symposium, here in Yang-yang, Kang-won-do, for the International Year of Forests 2011. Also, I would like to welcome you all; forest experts, government officials, and other honoured guests from both home and abroad.

Here, the eastern cost area of Kang-won-do, has been susceptible to natural disasters having forest fires and drought during the spring and fall, flood and typhoons in the summer, and snowfall in the winter. The consequences of forest fires have not just been forest damage but have extended to the loss of domiciles and forest crops which threaten the basic livelihood of local people.

Here in Yangyang, during the forest fire which occurred on the 4th of April, 2005, a thousand year old Buddist temple, Naksan-sa sustained severe damage and the huge bronze bell, one of our national treasures was also destroyed.

As well as Yangyang forest fire, small to mega forest fires, such as Go-sung forest fire in 1996, Dong-hae-an forest fire in 2000, have continuously occurred in the eastern area of Kang-won-do, which has caused great damage to forests and have resulted in local people suffering as a consequence.

However, since the Yangyang forest fire in 2005, no such big fire has occurred. I believe that this is the result of the continuous efforts made by Korea Forest Service, nation, the government, and military, towards successful forest management.

This symposium, held here in Yangyang today, is more meaningful as it is the 10th year since the Dong-hae-an forest fire occurred in 2000. I hope that studies on forest management, including its current situation, fire prevention, fire control techniques, and rehabilitation of forests presented today can contribute greatly to forest fire prevention.

I'd like to thank you all again for being here today and I hope that through this international symposium, we can foster forest fire prevention techniques and reduce damages from the fire in order to preserve our forests.

Lastly, I also would like thank those of you who helped us to prepare today's event. Thank you.

Sun Do Choi
Vice president
Kangwon National University

KEYNOTE SPEECH I

International Protocols and Agreements on Cooperation in Wildland Fire Management: Needs, Current Status, and the Way Ahead in the Asian Region and at Global Level

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Abstract

In the endeavor of protecting global vegetation resources from wildfires and excessive fire application in land use and land-use change, including the protection of human and environmental security from the adverse direct impacts or secondary effects of wildland fires such as air pollution and emissions affecting the global atmosphere and climate, countries are increasingly willing to share expertise and resources in fire management, including transboundary cooperation and mutual assistance in wildland fire emergencies. Attempts to further develop transboundary cooperation includes sharing of scientific knowledge and practical expertise in integrated fire management, i.e. the integration of natural fires and managed prescribed fires in sustainable ecosystem management and land use. In order to realize systematic and efficient international cooperation the international wildland fire community needs agreements and internationally agreed guidelines that provide protocols and procedures and thus enhance governance, efficiency and efficacy for international cooperation.

Keywords: Wildfire, wildland fire, fire management, international cooperation, legal agreements, voluntary agreements, UNISDR Global Wildland Fire Network, UNISDR Wildland Fire Advisory Group

1. Introduction

Increasing vulnerability of societies and the environment to wildfires is noted globally. The severity and destructivity of wildfire disasters, which in many cases exceed the response capabilities of a country affected, and the transboundary consequences of fires are prompting governments to develop cooperative mutual (reciprocal) agreements on emergency assistance at bilateral level, and in some cases at multilateral level.

Several international (global) conventions, such as the three “Rio Conventions” (CBD, CCD and FCCC), are examples of international legal agreements that provide rationale and catalogues of commitments for signatory countries to protect the global environment. However, none of the international legally binding conventions or any informal or voluntary international instrument, such as the “Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters”, is addressing the wildland fire problem explicitly. There are also no protocols in place that are providing internationally accepted standard methods and procedures for countries providing and receiving assistance in wildland fire emergencies that would ensure efficiency and inter-operability of cooperating parties.

In preparation of and following up the International Wildland Fire Summit of 2003[1] the international wildland fire community had taken steps to develop first concepts, templates and guidelines with widely agreed principles and best practices in fire management and incident command. Detailed operational standards are needed now to facilitate the exchange of fire fighting resources, including aviation, management personnel, and equipment. The UN Disaster Assessment and Coordination (UNDAC) and the International Search and Rescue Advisory Group (INSARAG) Guidelines[2] and the principles laid down in the “Rosersberg Initiative – Improving the international environmental emergency response system” may serve as examples for developing interoperable standards, protocols, Standard Operating Procedures (SOPs) and rules of engagement.

At the level of multilateral bodies, e.g. under the umbrella of the Association of South East Asian Nations (ASEAN), the UN Economic Commission for Europe (UNECE), the Asia-Pacific Economic Cooperation (APEC), the European Union (EU) or the Southern African Development Community (SADC) recent developments have revealed an interest of countries to enhance capability in regional transboundary cooperation in fire management. Experience gained in bilateral (reciprocal) agreements, including the common use of the Incident Command System (ICS) as practiced in exchanges under bilateral agreements

1 http://www.fire.uni-freiburg.de/summit-2003/introduction.htm
2 http://www.reliefweb.int/undac/documents/insarag/guidelines/topics.html and http://www.usar.nl/upload/docs/insarag_guidelines_july_2006.pdf

between North American countries (U.S.A., Canada and Mexico) and between the U.S.A. and Canada on the one side, and Australia and New Zealand on the other side, may serve as examples for developing regional agreements or protocols.[3]

The Global Wildland Fire Network (GWFN)[4], a voluntary network borne as an activity of the UNECE/FAO Team of Specialists on Forest Fire[5] and operating under the United Nations International Strategy for Disaster Reduction (UNISDR), facilitated by the UNISDR Wildland Fire Advisory Group (WFAG) and the Global Fire Monitoring Center (GFMC)[6], is promoting international cooperation in wildland fire management, notably through capacity building in wildfire prevention, preparedness and suppression, and the development of standardized procedures for use in international wildfire incident response.

Long-term the GWFN is also aiming at the development of an International Wildland Fire Accord (voluntary or binding under international law), which would be based on the rationale that there is a common international interest in protecting of global vegetation cover against degradation or destruction and that common endeavors in fire management will contribute to disaster risk reduction, e.g., direct fire damages to human assets and ecosystems, fire-generated smoke pollution affecting human health and security, release of greenhouse gases, secondary disasters such as landslides, erosion, and floods, as well as threats to biodiversity.

In the following sections examples of achievements and some currently ongoing activities are highlighted, which reflect some progress in the dialogue to enhance international cooperation in wildland fire management. Within the Asia Cluster of the Global Wildland Fire Network, consisting of the four UNISDR Regional Wildland Fire Networks of North East Asia, South East Asia, South Asia and Central Asia this dialogue has been initiated during the first regional meeting in Busan, South Korea, February 2009, and will be continued at this International Forest Fire Symposium commemorating the International Year of Forests 2011.[7]

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[3] See special issue of UNECE/FAO International Forest Fire News (IFFN) No. 29, with examples of agreements and Annual Operating Plans: http://www.fire.uni-freiburg.de/iffn/iffn_29/content29.htm

[4] http://www.fire.uni-freiburg.de/GlobalNetworks/globalNet.html

[5] http://www.fire.uni-freiburg.de/intro/team.html

[6] http://www.fire.uni-freiburg.de/

[7] Note: An earlier version of this paper has been presented at the 5th International Wildland Fire Conference, South Africa, 9-13 May 2011.

2. Progress in regional cooperation in fire management

2.1 Association of South East Asian Nations (ASEAN)

As a consequence of extended fire and smoke episodes since the early 1980s and especially in the 1990s ten member states of the Association of Southeast Asian Nations (ASEAN) started to negotiate an agreement at regional ASEAN level to address regional air pollution caused by land-use fires and wildfires. In June 2002 the Agreement on Transboundary Haze Pollution was adopted and came into force on 25 November 2003, with nine states currently participating (Brunei Darussalam, Cambodia, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Viet Nam).

The Agreement is the first regional arrangement in the world that binds a group of contiguous states to tackle transboundary haze pollution resulting from land and forest fires.[8] The Agreement requires the Parties:

- cooperate in developing and implementing measures to prevent, monitor, and mitigate transboundary haze pollution by controlling sources of land and/or forest fires, development of monitoring, assessment and early warning systems, exchange of information and technology, and the provision of mutual assistance;
- respond promptly to a request for relevant information sought by a State or States that are or may be affected by such transboundary haze pollution, with a view to minimizing the consequence of the transboundary haze pollution; and
- take legal, administrative and/ or other measures to implement their obligations under the Agreement.

The Agreement establishes an ASEAN Coordinating Centre for Transboundary Haze Pollution Control to facilitate cooperation and coordination in managing the impact of land and forest fires in particular haze pollution arising from such fires. Pending the establishment of the Centre, ASEAN Secretariat and ASEAN Specialized Meteorological Centre (ASMC) co-performed the interim functions of the Centre.

Quite noticeably, Indonesia is missing from the list of state parties. This presents a particularly acute problem for the region since Indonesia is by far the biggest source of the fires and haze (Khee-Jin Tan, 2005; Nguitragool, 2011). In

[8] See ASEAN website „Haze Online“: http://haze.asean.org/hazeagreement/, and the full text of the agreement at: http://haze.asean.org/docs/1128506236/ASEANAgreementonTransboundaryHazePollution.pdf/view

early 2011 Indonesia indicated its willingness to push the ratification.[9]

2.2 European Union (EU)

In the 1980s and 1990s there was some exchange of expertise on firefighting within the EU but little in the way of formal cooperation. The European Union Civil Protection Mechanism, was established in 2001 and further strengthened in 2007. It provided a new capacity for coordination for Europe. It now plays a central role in the EU forest fire risk prevention and forest firefighting coordination at EU level. There are currently 31 countries participating in the Mechanism ("Participating States"): The 27 Member States of the European Union (EU) together with Iceland, Liechtenstein, Norway and Croatia. The Mechanism, which is managed by the European Commission, has tools to cope with wildfires in three phases of the disaster management cycle. The main responsibilities and the tools allocated to the European Commission are outlined as follows[10]:

Monitoring and prevention

The core body in the operation of the European Union Civil Protection Mechanism is the Monitoring and Information Centre (MIC). The MIC's three major roles are:

- to provide a coordination platform for exchange of requests for assistance and offers of resources among Participating States;
- to be an agent for information exchange and dissemination on natural and man-made disasters worldwide and the Mechanism interventions;
- to be a coordinator that identifies gaps and develops solutions on the basis of the information it receives, and facilitates the pooling of common resources where possible, and supplies expert teams in the field of disaster to tackle the problems more effectively.

The Common Emergency Communication and Information System (CECIS)

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[9] http://www.fire.uni-freiburg.de/media/2011/01/news_20110122_id.htm

[10] Note: This general description of the EU Mechanisms has been taken from the introduction to the report „Study on wild fire fighting resources sharing models", prepared by GHK Consultants to DG ECHO, European Commission (October 2010), in which the author participated (the study is not yet published).

facilitates coordination between the MIC and national authorities. The main tasks of CECIS include hosting a secure and reliable database on potentially available assets for assistance; handling requests for assistance on the basis of these data; and facilitating the exchange of information and documenting all action and message traffic.

The MIC receives fire risk assessment information from the European Forest Fire Information System (EFFIS). This web-based platform, which consists of a scientific and technical infrastructure, was developed jointly by the European Commission Joint Research Centre and Directorate General Environment (European Commission).

Preparedness

The EU Civil Protection Mechanism intermediates dissemination activities and exchange of best practice among Participating States and provides training programmes and exercises to intervention teams. It organizes informative activities, seminars, conferences and pilot projects on the main aspects of interventions.

It also provides access to the assets in the European Union Forest Fire Tactical Reserve (EUFFTR), a pilot project designed to step up cooperation between Member States on combating forest fires during high risk seasons. The project, to which two Canadair CL-215 aircraft were allocated during the summers of 2009 and 2010, was activated in the cases where Member States were not in a position to provide assistance to a requesting country due to their aerial resources being needed in their own territory or because they could not reach the fire site quickly enough.

The Mechanism develops implementing rules for module development and administers the CECIS module database.

Response

Through the EU Civil Protection Mechanism, the European Commission is able to:

- Mobilize small teams of experts to the site of an emergency;
- Provide and distribute information during an emergency/intervention;
- Play a facilitating role in the coordination of assistance requests and offers

from Participating States;
- Coordinate with other actors at the international level and with other EU services; and
- Provide co-financing for the transport of assistance to the affected areas, on the request of the offering Participating States.

The EU Civil Protection Mechanism is well-accepted and increasingly used by Participating States. Twenty-eight requests for assistance were received by the MIC in 2009-10 from the EU and 18 from third countries, compared with just three in total in 2002. The Mechanism coordinates and facilitates voluntary efforts – each Participating State decides on its contribution on an ad hoc basis.

2.3 Asia-Pacific Economic Cooperation (APEC)

In October 2010 the first "International Conference on Forest Fires: Management and International Cooperation in Preventing Forest Fires in APEC Region" was convened at the initiative of the Russian Federation and aimed to strengthen cooperation between the emergency services of the APEC member economies in order to express readiness of the region to reduce the risks of disasters.[11] Through an in-depth and comprehensive analysis of the problem of forest fires in the APEC region and the world, the conference identified the urgent necessity and importance of joint efforts, mutual help and cross-border cooperation in forest fire risk reduction. The conference released the "Khabarovsk Recommendations on Management and International Cooperation in Preventing Forest Fires in the APEC Region". Among other the following priority directions of international cooperation under APEC were proposed:

- Development of an international mechanism to monitor and enhance responsibility of the APEC member economies to ensure forest fire protection on their territories, and coordinate action under APEC with the existing institutions of international cooperation, such as UNISDR Global Wildland Fire Network, ASEAN, UNECE and others.
- Promotion of economic cooperation in projects that aim to reduce the degree of fire risk and restoration of forests on lands degraded by fire and non-sustainable forest management;
- Development of bilateral agreements on cooperation in fire management,

[11] http://lesscentr.ru/en/en/index0.htm

particularly between APEC economies sharing common borders, and a regional voluntary agreement on cooperation in fire management, aiming at harmonizing cooperation with neighboring regional entities such as the UNECE and ASEAN, particularly in the light of overlapping membership of some economies.

- Development of long-term fire management strategies in each economy that allow for the mitigation of the consequences of climate change.
- Improvement of strategic and operational early warning of forest fire risk in the APEC region as a regional activity to be coordinated with the Global Wildland Fire Early Warning system.
- Conduct regular consultations, and exchange knowledge and best practices informed by a high level of expertise within directions of APEC.
- Reconvene and contributing to the 5th International Wildland Fire Conference scheduled for 2011 (South Africa), and the following conference scheduled for 2015 (South Korea).

2.4 Southern African Development Community (SADC)

In the last two decades, vegetation fires have become a major concern in the region of the Southern African Development Community (SADC) with regard to the negative impacts they have on the environment and humans' welfare.[12] Uncontrolled (un-prescribed) wildfires cause forest and vegetation degradation and related biodiversity loss resulting in immediate and long-term impacts on the livelihoods of local communities and upstream impacts on national and regional economies. Fires in the tropical environment are a major contributor to tropical forest degradation, where over time frequent fires lead to savannization in these areas. However, fires are also needed to maintain healthy ecosystems and biodiversity of African savannah and grassland vegetation types, many of them being adapted to regular fire influence. Prescribed or controlled burning is used to meet objectives often essential to sustaining livelihoods. Fire is used also for conservation reasons, removal of old growth, suppression of bush encroachment and stimulation of the growth of grazing grass as well as the removal of fuel with the aim of pre-empting dangerous wildfires at the peak of the fire season.

The SADC region of 14 Member States is home to 238 million people of

[12] The information provided in the chapter are taken from the SADC Regional Fire Management Programme Document, draft proposal (June 2010). Web source: http://www.fire.uni-freiburg.de/GlobalNetworks/Africa/SADC%20Regional%20Fire%20Management%20Programme%20Document-Final-6.pdf

which approximately 75% are rural based. The perceived rise in the number of wildfires negatively affects these rural communities, many living near forests that provide them with their basic needs. The on-going process of climate change has the potential to exacerbate this situation by altering the frequency, intensity, severity and seasonality of fires in the SADC region.

A SADC regional fire management programme has been proposed in 2010. It provides a framework for cooperation on fire management issues across national boundaries. Fire management is a technical, socio-cultural and political challenge that requires an effective network of willing partners that include governments, the private sector, local communities and international partners to find the appropriate balance between developing and conserving natural resources and managing unwanted fires while at the same time promoting the safe use of beneficial fires. The programme intends to foster cooperation and collaboration on fire management on a regional basis to move towards integrated environmental policies and fire management practices. The programme pursues a multiple stakeholder approach working closely with regional and international organization to support five areas of fire management: legal and regulatory aspects of fires, community based fire management, institutional strengthening and establishment of a fire management coordination centre, generation and dissemination of relevant fire information for detection and early warning as well as lastly associated capacity building in the respective areas.

The envisaged programme is based on the SADC Protocol on Forestry of 2002, which forms the policy framework for sustainable forest management in the SADC member states. One of its objectives is to achieve effective protection of the environment, and safeguard the interests of both the present and future generations.

The SADC Forestry Strategy of 2010 is based on the vision is to develop and maintain a vibrant and evolving forest sector that contributes to rural development, poverty reduction and, industrial progress, while retaining the vital ecosystem services of forests such as, water supply, climate change mitigation, and protecting biological diversity and thereby providing the motivation for countries to cooperate for their protection, management, and sustainable use. The purpose of the strategy is to provide a framework for both regional cooperation and international engagement on forest issues; paying special attention to issues that transcend national boundaries and to encourage concerted action by SADC Member States in the management, conservation and sustainable use of their forests. The strategies mission aims to facilitate cooperation among member states to ‘promote the active protection, management and sustainable use of forest resources, through, sound policy guidance and the application of requisite skills and the best available technology, in order to enjoy the multiple benefits of forests in perpetuity.

There is increased willingness by SADC member states to cooperate on fire management on a regional and international basis. There is also recognition that a regional framework, based on cross border, regional and international cooperation is required to address issues of national, regional and transboundary fire management. Member states have expressed the need for a regional agency or centre to foster and coordinate such cooperation and information exchange in fire management. Establishing a regional agency or centre responsible for collection and analysis of fire related data and formulating standardised rules, guidelines and procedures will ensure reliability and coordinated dissemination of relevant information as well as guide policy processes and development. Furthermore it would spearhead the promotion of integration of Community-Based Fire Management (CBFiM) into national policies and fire management strategies.

The expected activities and outcomes of the SADC Regional Fire Management Programme include the establishment of a Regional Fire Management Coordination Center. This center will also facilitate and coordinate international and regional cooperation in fire management providing a framework within one country may request and receive wildfire suppression resources from another country and to encourage cooperation and exchanges on other fire management activities such as training and lessons learnt. A SADC fire management programme will facilitate the development of a SADC Memorandum of Understanding (MoU) outlining cross border cooperation to combat transboundary fires by fire teams from different Member States as well as operational guidelines for the regional coordination centre.

The programme intends to foster regional level interaction by developing guiding policy frameworks and procedures for several aspects of fire management. During the Consultative Workshop on the Development of a SADC Regional Fire Management Programme (January 2010, Maputo) participants from all SADC member states identified and compiled capacity development measure to be carried out by all SADC member states to ensure success of a regional fire management program. The project includes the following components:

- Establishment of a Regional Fire Management Coordination Center. Objective: To promote the establishment of a regional fire management coordination

centre for improved stakeholder cooperation and collaboration
- Reform and Harmonization of policies and Procedures. Objective: To secure essential policy harmonization at national and regional level to provide the basis for controlling harmful fires and promoting the safe use of beneficial fires within SADC
- Community based fire management. Objective: To secure essential policy harmonization at national & regional level to provide the basis for controlling harmful fires and promoting the safe use of beneficial fires within SADC
- Fire information. Objective: To improve production, access, dissemination and application of fire information within the region
- Capacity development. Objective: To increase awareness of and knowledge in balanced and integrated fire management and its elements

In late 2010 a trilateral project between South Africa, Tanzania and Germany (Trilateral Cooperation Fund – TRI-CO Fund) has been launched to develop improved coordination and exchange of techniques, resources, science and other capacity building measures related to fire and fire management amongst contributing parties and SADC member states (duration: 2010-2013).

2.5 UN Economic Commission for Europe (UNECE)

Within the last decade the region of the United Nations Economic Commission for Europe (UNECE) has experienced a number wildfire episodes that have resulted in severe environmental damages, high economic losses and considerable humanitarian problems.[13] Reasons and underlying causes of extreme wildfires may be quite different throughout the region – a region which is extending over the whole temperate-boreal northern hemisphere, bearing a large variety of ecosystems and land-use systems. However, there are issues in common. For instance, in the Eurasian part of the region many neighboring countries are sharing similar natural, cultural and social conditions that are determining the occurrence and impacts of wildfires. Countries are also confronted with newly arising or escalating fire problems resulting from changes in the political, social and economic environment, land-use change and climate change.

[13] This section has been derived from the planning document for the UNECE/FAO Regional Forum on Cross-boundary Fire Management, to be organized by the UNECE/FAO Teams of Specialists on Forest Fire through its Coordinator – the Global Fire Monitoring Center (GFMC), Germany, and supported by the Council of Europe as a contribution to the "UN International Year of Forests" in 2011. For details and updates: see website of the UNECE/FAO Teams of Specialists on Forest Fire: http://www.fire.uni-freiburg.de/intro/team.html

On the other hand progress is noted in advancing multinational cooperative efforts in wildland fire research and related sciences and in transboundary cooperation in fire management. At national levels increased openness of sectoral mandated institutions to overcome historic division of roles of agencies in fire management is noted.

There is a high interest of governments, national agencies, international organizations and civil society in the UNECE region to address the increasing threats or newly arising problems by fire management solutions that could be developed collectively, and thus economically, allowing inter-operability in fire management between nations and regions.

In early 2012 the “UNECE / Council of Europe Regional Forum on Cross-boundary Fire Management” will be organized at the United Nations in Geneva by the Global Fire Monitoring Center (GFMC) and the Secretariat of the UNECE/FAO Forestry and Timber Section, and co-sponsored by the Secretariat of the Euro-Mediterranean Major Hazards Agreement (EUR-OPA), Council of Europe.

The conference will elaborate recommendations to UNECE and CoE member states to take advantage of recent insights and solutions of contemporary and expected future wildfire problems. Main focus of the conference will address the situation in countries in which progress of enhancing fire management capabilities is limited, e.g. as a consequence of political and administrative transition as well as difficult economic conditions, or countries with significant or extraordinary fire situations, which would benefit from the experience of their neighbor countries.

The outcome of the conference will build on existing and already proposed initiatives, e.g.:

- New approaches in integrated vegetation management with regards to renewable energy concepts and carbon storage, some related to the UNFCCC endeavor to reduce deforestation and forest degradation in the frame of the international climate and forest regimes, with relevance to wildfire hazard reduction and opportunities for fire management to contribute;
- Wider application of prescribed fire in nature conservation, forestry and landscape management, with encouraging progress of countries cooperating under the “Eurasian Fire in Nature Conservation Network”[14] and similar

[14] http://www.fire.uni-freiburg.de/programmes/natcon/natcon.htm

initiatives;
- Exploitation of the results of successfully completed international fire research projects for developing adequate public policies affecting fire management and operational fire management, e.g. the latest accomplished multi-national "Fire Paradox"[15] project, or the ongoing development of the multinational Alpine Forest Fire Warning System (ALPF FIRS)[16];
- Introduction and further development of competency-based fire management training standards for achieving qualifications for fire fighters, foresters and land managers, e.g. the "EuroFire Competency Standards"[17];
- Strengthening dedicated networks of wildland fire specialists, agencies and other representatives of civil society, e.g. the six Regional Wildland Fire Networks of the Global Wildland Fire Network that are covering the UNECE region;
- Application and further development of existing and development of new bilateral agreements on reciprocal transboundary assistance in wildfire emergencies all over the ECE region;
- Endeavor to enhance governance of UNECE member states to provide and receive assistance in wildfire (and other environmental) emergency situations by setting up standards, protocols and agreements, in cooperation with procedures evolving under the lead of the UNEP/OCHA Joint Environment Unit and the UN Advisory Group on Environmental Emergencies, e.g., the proposed creation of an Environmental Emergencies Center (EEC);
- Follow up of the recommendations of regional groups, projects and programmes, or earlier regional conferences to enhance international cooperation in fire management in the UNECE region and adjoining regions, e.g. the recommendations for the development of a "Regional Strategy for Cooperation in Fire Management in Southeast Europe" of 2006[18], the outcomes of expert meetings such as the recommendations of the workshop "Assessment of Forest Fire Risks and Innovative Strategies for Fire Prevention", an activity of the Ministerial Conference for the Protection of Forests in Europe (MCPFE) of 2010, or the European Commission network of fire experts and its information system, the European Forest Fire Information System (EFFIS)[19]; or the recommendations from projects supported by the Environment and Security Initiative (ENVSEC) addressing wildland fire, human security

[15] http://www.fire.uni-freiburg.de/programmes/other/intr.html
[16] http://www.alpffirs.eu/
[17] http://www.euro-fire.eu/
[18] http://www.fire.uni-freiburg.de/GlobalNetworks/SEEurope/Strategy-WFM-RSEEWFN-2-02-05-2006.pdf
[19] http://effis.jrc.ec.europa.eu/

and peace in the EECCA region[20], and the outcomes of the International Conference on Cross-Boundary Fire Management (Irkutsk, Russia, 2010)[21] and the APEC Conference on Forest Fire Management and International Cooperation in Fire Emergencies of the Asia Pacific (Khabarovsk, Russia, 2010)[22].

The outcomes of the forum shall be regarded as complementary and value-added to existing agreements and mechanisms. The conference will be held as a contribution to the "UN International Year of Forests" (2011) to further the objectives of the international forest and climate regimes and shall contribute to the evolving of an "international wildland fire regime" as envisaged by the UNISDR Global Wildland Fire Network.

A large number of countries of the UNECE region are members of the Council of Europe, member states of the European Union and signatory states of the MCPFE, and are all concerned of the impact of climate change on forests and forest destruction by fire. There is a collective demand for robust forest policies. However, wildland fires are not only impacting the protection and functioning of forest ecosystems. Fire use and wildfire occurrence in the cultural landscapes of the region shaped by agriculture, pastoralism and forestry, have considerable impacts – both in negative and positive ways – on landscape patterns, land productivity, biodiversity and the atmosphere – with implications on air quality, human health and security, and climate change.

The UNECE Convention on Long-Range Transboundary Air Pollution[23], the European Landscape Convention[24] or the Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention)[25] are examples of conventions that are addressing tangible and pressing regional issues and that are relevant – although not yet explicitly referred to – a potential regional "wildland fire regime".

Thus, the overall aim of the Forum will be a first step towards the development of an agreement on international cooperation to enhance fire management

[20] Note: The objectives of the Forum are not intended to interfere or whatsoever with the Community Civil Protection Mechanism of the European Union (EU) and its efforts of coordination of international / multi-national assistance in (wildfire) emergencies in Europe and outside the EU.
[21] http://www.fire.uni-freiburg.de/GlobalNetworks/CentralAsia/CentralAsia_6.html
[22] http://lesscentr.ru/en/en/index0.htm
[23] http://www.unece.org/env/lrtap/
[24] http://www.coe.int/t/dg4/cultureheritage/heritage/Landscape/default_en.asp
[25] http://www.plantaeuropa.org/pe-wider_context-Bern.htm

capability in the region. Right from the beginning of the political and technical planning and consultation process in preparation of the Forum is considered to be connected to the outcomes of the 5th International Wildland Fire Conference (May 2011) and a follow-up process.

2.6 Bilateral reciprocal agreements with multilateral character: Examples

Looking back a decade the wildland fire season in the United States during the year 2000 at that time was the worst fire season in more than 50 years. Almost 100,000 fires burned more than 2.8 million hectares of forest and range lands. This was approximately twice the U.S. ten-year average. The season was long and difficult and firefighters faced dangerous burning conditions throughout the western U.S.A.[26]

Faced with this unprecedented situation, and with a forecast for a continuing hot and dry weather pattern, fire managers realized they would need to reach beyond U.S. borders for assistance. During the remainder of the 2000 fire season, the U.S. received assistance from more than 1200 Canadian firefighters, 96 fire specialists from Australia and New Zealand and 20 Mexican firefighters. These additional resources performed important roles in the U.S. fire fighting efforts. Some international fire fighters provided much needed support to fire crews on the fireline while others performed as middle managers on incident management teams. International agreements with Canada and Mexico were in place prior to the 2000 fire season but none existed with Australia and New Zealand.

Why Did the U.S. go to Australia and New Zealand?

U.S. fire managers have had informal study group exchanges with Australia and New Zealand for more than 50 years. These exchanges provided opportunities to share information about each other’s programs and experiences. Based on that exchange relationship and the knowledge of the Australian and New Zealand firefighting systems, when the U.S. fire situation reached a critical level in 2000, the U.S. approached Australia and New Zealand and asked for their help. The 96 fire experts that came to the U.S. were integrated into the U.S. fire fighting

[26] The essential parts of this section are taken from USDA Forest Service (2003).

organization where they served in middle management positions on fires, freeing up U.S. fire managers to take on more critical tasks.

The Relationship in 2000

The justification for seeking the assistance of Australia and New Zealand in 2000 was based on an assumption that a U.S. Public Law called the "Wildfire Suppression Assistance Act," gave the authority to the U.S. Secretaries of the Interior and Agriculture to enter into assistance agreements, especially because of the critical situation facing fire managers on the fire lines. U.S. fire managers, who coordinated this activity during 2000, did not understand the clearance and vetting processes required by the U.S. Department of State prior to putting Australia and New Zealand fire fighters in harms way on the fire lines. Fortunately, no serious incidents occurred, and all of the Australian and New Zealand firefighters returned home safely and from all accounts, they performed ably and were a credit to their countries.

When the 2000 fire season was over, U.S. fire managers understood that the assumed authority used to bring Australia and New Zealand fire fighters over would not be viable in the future. And the biggest issue that arose was a concern about tort claim liability. Solicitors and risk managers from Australia and New Zealand, upon review of U.S. law did not feel that their firefighters were provided sufficient legal coverage by the U.S., if an Australian or New Zealand firefighter, even properly performing his duties, was involved in unforeseen fire line incident which caused injury or damage to other parties. New arrangements needed to be developed and signed by all parties before the U.S. could once again request and receive help from Australia and New Zealand.

The 2001 Christmas Fires in Southeastern Australia

The devastating fires around Sydney and other areas of southeast Australia in 2001, like the U.S. fires in 2000, drew worldwide attention. The U.S., trying to return the favor of help that it received in 2000, offered to provide some assistance. Thanks to a break in the weather, the professionalism of the their fire fighters, and to the incorporation of some lessons learned from their experiences in the U.S. in 2000, Australian fire managers were able to control their fires. However, had U.S. help been needed, the ability and timeliness of the U.S. to provide assistance would have been greatly hampered by the lack of signed arrangements and operating plans. This once again highlighted the need for the completion of more formal arrangements and protocols between the countries which would meet the concerns of all parties.

The 2002 U.S. Fire Season

After a quiet wildland fire season in 2001 in the U.S., the 2002 wildland fire season was just as challenging to fire managers as 2000. As conditions in the forests and rangelands of the Western U.S. worsened and record setting hectares burned in several states, the U.S. again prepared to call for international assistance. However, Canada which provided valuable and lengthy support to the U.S. in 2000 faced its own fire problems stretching from Quebec to British Columbia. And there were still unresolved issues with arrangements and protocols with Australia and New Zealand.

Throughout 2001 and up to August of 2002 U.S., Australian, and New Zealand fire managers, risk managers and solicitors had been proposing and reviewing potential options to solve the liability concerns raised after the 2000 fire season. One alternative that was explored was purchasing sufficient liability insurance to meet risk managers requirements, but the cost was prohibitive, and the policies would have been too complex. The best possible solution was to change U.S. law that would give any international firefighter brought to the U.S. under the “Wildfire Suppression Assistance Act,” tort liability coverage equivalent to that provided to U.S. Government fire fighters. In early August the bill was passed and signed by the President of the U.S. The language in the bill provided the assurance required by Australian and New Zealand and U.S. fire managers were once again allowed to request international assistance from Down Under. Signatures of the Secretaries of Agriculture and the Interior were quickly inked on the official Arrangement papers and posted overnight to Australia and New Zealand. The Australian States of Victoria, New South Wales, Tasmania, Western Australia, and South Australia and New Zealand signed the Arrangements. Within a week of the passage of the legislation, 50 Australian and New Zealand fires specialists were on U.S. fire lines filling, as they did in 2000, critical mid-level management fire positions in operations and aviation.

The 2002-2003 Bush Fire Season in Australia

The 2002-2003 bush fire season in Australia saw some of the worst fires in over 50 years. The hardest hit states were Victoria and New South Wales. In later January of 2003, the State of Victoria requested U.S. assistance. Thirty six U.S. fire fighters went to Australia for a month. A twenty person hand crew worked shoulder to shoulder with Australian fire fighters on the fire line. An infrared scanning aircraft with crew and infrared photo interpreters was also sent. And two small incident management teams took on management responsibilities for portions of a massive fire in the Alpine Region of Victoria. The U.S. fire fighters shared their knowledge and experience with their Australian counterparts and also gained a great deal of respect for the challenges facing Australian fire fighters in the management and suppression of bush fires.

This request for U.S. assistance tested and solidified the two-way nature of the Arrangements signed in 2002.

The 2003 U.S. Wildland Fire Season

The 2003 wildland fire season initially did not appear that it would reach the proportions of needs that were required in 2000 and 2002. However, by mid-July the affects of a multi-year drought, record high temperatures and low humidity and the right weather conditions caused numerous large fires to rage out of control in the Northern Rockies. For the third time in four years U.S. fire managers were facing the need for more international assistance, and Canada, as in much of 2002, was busy suppressing devastating fires of its own in several provinces. And once again, based on the 2002 Arrangements, 40 Australian and New Zealand fire fighters came to the aid of the U.S.

The 2003 request reaffirmed the true value of being able to call upon Australian and New Zealand firefighters during extreme wildland seasons. It also began to seem routine.

Other Values of the Arrangements

Instituting these Arrangements not only provided for a clear mechanism to share fire fighting resources during critical times, it also established formal procedures for cooperative exchanges outside of critical fire season time periods. Knowledge of each other’s capabilities and systems before the fires start can pay important dividends in the heat of battle. These cooperative exchanges have the following objectives:

- To share information on training, qualification, and certification systems and requirements;
- To share knowledge about operational procedures and systems including ground and air operations;
- To observe each others prescribed fire programs;
- To study how each country uses fire fighting equipment and apparatus;
- To observe how each country uses relationships at national, state and local levels to coordinate and access firefighting resources such as volunteers;
- To share information on fire prevention and education.

The Future

Through mobilizations of firefighters and numerous exchange activities, these arrangements have repeatedly proven the value of having effective, flexible, cooperative and formal relationships. These Arrangements are not static but must be periodically reviewed, adjusted, and re-approved by the signatories. The U.S. will continue to work with its partners in Australia and New Zealand to improve and expand on these valuable relationships in order to cooperatively address the common global challenges of wildland fire management.

3. Progress in developing guidelines, protocols and standards for increasing efficiency and effectiveness of transnational cooperation

In addition to bi- and multilateral agreements the international community has developed during the last years a number of proposals, templates and models for improving governance, efficiency and effectiveness of international cooperation in wildfire disaster risk reduction, management and response. The “tools” include an international wildland fire terminology, methods for wildland fire risk identification at national, regional, and global levels, non-binding guidelines for fire management and smoke management, including dedicated eco-zonal fire management guidelines. The use of a standardized, commonly accepted wildland fire incident management system for international cooperation in a disaster situation has been proposed. The global wildland fire network has also developed a template for international wildland fire management cooperation agreements for the use by countries interested in entering into formal relationships and agreements on reciprocal assistance with other countries facing similar issues. Training in fire disaster management through development of internationally compatible standards and competency, as well as certification of international fire responders, are important elements of improving international cooperation in wildland fire management. In the following some key activities are described.

3.1 International Wildland Fire Terminology

The very basic prerequisite for international cooperation in fire management is a commonly agreed terminology, a language that is understood by all partners intending to develop cooperation in fire management. In a number of countries very useful terminologies have been developed. This includes English-speaking countries in which fire terminologies are becoming increasingly compatible at international level. However, terminologies show some differences in the use and meaning of terms. In some countries specific terms have been developed that are not in use in other countries. As the English language is becoming the major language used for international cooperation in fire management it has been proven useful to develop a basic English glossary with English explanations of the terms, which would then be useful for translation. The "Global Wildland Fire Management Terminology", first published by FAO (1986) was updated by the Global Fire Monitoring Center (GFMC) on behalf of FAO in 1999. The glossary has not been printed as it is considered a dynamic document, open for any changes considered necessary. The glossary is available as an interactive search engine on the web.[27] In the 1999 version, the only non-English language updated was German. FAO added French and Spanish.[28] In 2010 the GFMC published the Russian and Mongolian version (together with English and German).[29]

3.2 International Statistical Wildland Fire Data Collection

Internationally agreed methodologies and procedures for the establishment of fire databases and formats for national fire reporting are not in place. Both databases and national fire reports (assessments) are important for decision support at national, regional and international levels, as well as for assessment of needs and impacts and for targeted cooperation in fire management.

The FAO "Global Forest Fire Assessment 1990-2000" (a special report of

[27] http://www.fire.uni-freiburg.de/literature/glossary.htm
[28] http://www.fao.org/forestry/firemanagement/13530/en/
[29] http://www.fire.uni-freiburg.de/literature/glossary.htm

the Global Forest Resources Assessment 2000 [FRA-2000])[30] and the reports from 12 Regional Wildland Fire Networks, summarized and evaluated in the "Fire Management Global Assessment 2006"[31], revealed the lack of current, consistent and coherent statistical data sets. The concept of the detailed "Global Wildland Fire Assessment 2004", initiated by the GFMC, was used for a number of national reports submitted to the Regional Wildland Fire Networks.[32] However, the assessment covered only a marginal fraction of countries.

Information flow from national and regional level to an international clearing house for receiving, processing and disseminating fire data as well as other fire information back to countries and other users, connected with a network of national fire management agencies, must be ensured. The earlier recommendation by the UNECE/FAO/ILO in 1996 to establish a Task Force to produce a proposal for a harmonized and coordinated data collection and reporting system that will meet the demands of various user communities is therefore repeated with urgency.[33]

The next step forward to overcome uncertainties and inconsistencies of fire inventories is the development of a global satellite-based vegetation fire inventory. The Global Observations of Forest and Land Cover Dynamics (GOFC/GOLD) project, an element of the Global Terrestrial Observing System (GTOS) programme, sponsored by the Integrated Global Observing Strategy (IGOS), provides a forum for international information exchange, observation and data coordination, including calibration and validation of sensors and algorithms, and a framework for establishing the necessary long-term monitoring systems. The GOFC/GOLD Fire Mapping and Monitoring Theme is aiming at refining and articulating the international observation requirements and making the best possible use of fire products from the existing and future satellite observing systems, for fire management, policy decision-making and global change research.[34]

3.3 Template for International Wildland Fire Management Cooperation

The International Wildland Fire Summit of 8 October 2003 provided an

30 Global Forest Fire Assessment 1990-2000: http://www.fao.org/docrep/006/ad653e/ad653e00.htm
31 Fire Management Global Assessment 2006: http://www.fao.org/docrep/009/a0969e/a0969e00.htm
32 Global Wildland Fire Assessment 2004: http://www.fire.uni-freiburg.de/inventory/assessment.htm
33 Initial proposal for a global fire dataset by the ECE/FAO International Conference "Forest, Fire, and Global Change": http://www.fire.uni-freiburg.de/iffn/org/ecefao/ece_3.htm#Appendix%20I
34 GOFC/GOLD Fire Implementation Team: http://gofc-fire.umd.edu/; see also section 6 of this paper.

important forums for discussions of how to manage the future of international wildland fire management and share solutions to global problems. One of the outcomes of the Summit was a paper that offered a template and information on cooperation in wildland fire management to countries interested in entering into formal relationships and agreements with other countries facing similar issues.[35] The paper is intended to enhance current international coordination and cooperation by providing information on the following:

- A template outlining areas to consider when developing international cooperative agreements;
- Listing of the types of cooperation and assistance that may occur between countries;
- The responsibilities of countries sending assistance and of those receiving assistance;
- Websites containing information and examples of existing cooperative agreements and arrangements.

4. Internationally Compatible Training, Standards and Competency; Certification of International Fire Responders

Capacity building of human resources is a key prerequisite for efficient planning and implementation of sustainable fire management. Many countries that are in need of developing or reviewing fire policies or upgrading existing fire management methods and / or technologies, however, do not have own resources or expertise in capacity building in fire management. International cooperation in fire management is critical to support those countries. Priority for international cooperation should include advanced capacity building of target groups influential or responsible for developing fire policies, fire management planning and implementation. Multi-stakeholder, inter-sectoral and inter-agency approaches will be a key consideration. Non-government organizations and the private sector are important target groups to be included. Capacity building of instructors (training for trainers) is a key prerequisite for the success of building capacities at local to national levels. Several fire management handbooks are available that are tailored for use in countries that need to build fire management capacity by applying advanced knowledge in fire ecology and fire management, including participatory approaches in fire management (Community-Based Fire Management).[36]

[35] Published in International Forest Fire News (IFFN) No. 29, p. 10-14: http://www.fire.uni-freiburg.de/iffn/iffn_29/content29.htm

[36] http://www.fire.uni-freiburg.de/Manag/CBFiM.htm

Advanced international training courses for fire management specialists working at high-level positions in their home country and in the private sector will support the development of a culture of trans-national cooperation. Experience has been gained by several UN interagency training courses conducted by the United Nation University (UNU) and GFMC in Africa. A vision is to work through a decentralized worldwide network of training institutions in which donor organizations would collaborate. The development of training materials for international use is desirable.

The recently evolving “Partnership for Environment and Disaster Risk Reduction” (PEDRR) is currently developing training materials on “Ecosystem-based Disaster Risk Reduction for Sustainable Development”, in which a module “Integrated Fire Management” has been included.[37]

In the case of fire suppression first steps have been taken by developing competency standards that will ensure the smooth cooperation between firefighting units of different nations, i.e. their inter-operability in international missions. The EuroFire project, financed by the EU Leonardo da Vinci programme and implemented jointly by the Global Fire Monitoring Center (GFMC), the International Association of Fire and Rescue Services (CTIF) and Rural Development Initiatives Ltd. Between 2006 and 2008, reviewed competency-based wildfire training systems to identify best practice examples from Europe and around the world. This research was the basis for the production of competency-based basic training materials specifically for use in European countries. The key target end-user groups for the EuroFire project included: firefighters, the rural and land-based sector, sectoral organizations and education and training institutions.[38] Meanwhile EuroFire competency standards and training materials have been translated to Russian and tested in Europe and neighboring countries in East Europe / Caucasus in the frame of the Environment and Security (ENVSEC) programme.[39]

In future competency-based standards could serve for certification of firefighters to be deployed in fire response international missions.

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[37] www.pedrr.net
[38] EuroFire project website with competency standards and training materials for download: http://www.euro-fire.eu/
[39] http://www.fire.uni-freiburg.de/intro/Georgia-Training-Course-Detailed-Programme-RUS-ENG-4.pdf

5. Fire Management Guidelines

Fire Management Guidelines are needed for the various user levels, ranging from practical guidelines for local fire managers to guidelines for land-use planning and policy development. Guidelines must consider the specific natural (ecological) conditions of vegetation fire, as well as the social, cultural, economic and political environment. Valuable guidelines exist for local to global use. However, in many countries these guidelines are not known or not applied, or need to be adapted for the specific conditions, or need to be translated. Fire management guidelines for international use have been developed by international organizations since the 1990s and are available on the Internet:[40]

- International Tropical Timber Organization (ITTO) Guidelines on Fire Management in Tropical Forests (1997)
- The WHO/UNEP/WMO Health Guidelines for Vegetation Fire Events (1999)
- The FAO Guidelines on Fire Management in Temperate and Boreal Forests (2002)
- The Fire Management Voluntary Guidelines (2006)[41], with its implementation mechanisms, the Fire Management Actions Alliance (2007)[42]
- FAO Legislative Study “Forest fires and the law. A guide for national drafters based on the Fire Management Voluntary Guidelines” (Morgera and Cirelli, 2009).

While guidelines have been developed primarily to serve countries to develop sound, sustainable fire management capacities, including fire management policies and implementation strategies, they are also providing guidance on standard approaches or standards in fire management that have been proven internationally and which will facilitate international cooperation in fire management.

6. International Systems to be Shared: Global Wildland Fire Monitoring and Early Warning

There are a number of fire management support tools that are based on international Earth Observation Systems (EOS). These systems include spaceborne sensors for fire detection and monitoring, and terrestrial networks of

[40] Overview / portal: http://www.fire.uni-freiburg.de/literature/Fire-Management.htm
[41] http://www.fao.org/docrep/009/j9255e/j9255e00.htm
[42] http://www.fao.org/forestry/firealliance/en/

hydrometeorological services for recording and forecasting of fire weather.

The Global Observations of Forest and Land Cover Dynamics (GOFC/GOLD) project, an element of the Global Terrestrial Observing System (GTOS) programme, sponsored by the Integrated Global Observing Strategy (IGOS), provides a forum for international information exchange, observation and data coordination, including calibration and validation of sensors and algorithms, and a framework for establishing the necessary long-term monitoring systems. The GOFC/GOLD Fire Mapping and Monitoring Theme is aimed at refining and articulating the international observation requirements and making the best possible use of fire products from the existing and future satellite observing systems, for fire management, policy decision-making and global change research.[43] GOFC/GOLD and GFMC are closely interacting with the United Nations Office for Outer Space Affairs (UNOOSA), UNOSAT (Operational Satellite Applications Programme of the United Nations Institute for Training and Research – UNITAR), the International Charter "Space and Major Disasters", and the Group on Earth Observations (GEO) with its Global Earth Observing System of Systems (GEOSS).

In 2005 a global multi-hazard early warning system has been proposed in the Hyogo Framework for Action. Subsequently a concept for the development for a Global Early Warning System for Wildland Fires has been endorsed by the United Nations and presented at the Third International Conference on Early Warning (EWC-III), March 2006.[44] The Global Early Warning System for Wildland Fires, which is also a Task of the Group on Earth Observations (GEO)[45] aims at developing:

- Early warning of fire danger, on a global basis, that will provide international agencies, governments and local communities with an opportunity to mitigate fire damage by assessing threat likelihood and possibility of extreme behaviour enabling implementation of appropriate fire prevention, detection, preparedness, and fire response plans before wildfire problems begin.
- A robust global operational early warning framework with an applied system that will provide the foundation with which to build resource-

[43] GOFC/GOLD Fire Implementation Team: http://gofc-fire.umd.edu/

[44] Website of the Global Early Warning System for Wildland Fires: http://www.fire.uni-freiburg.de/fwf/EWS.htm

[45] GEOS Task DI-09-03B "Implementation of a Fire Warning System at Global Level" http://www.grouponearthobservations.org/cdb/ts.php?id=70

sharing agreements between nations during times of extreme fire danger.
- Development of local expertise and capacity building in fire management for system sustainability through technology transfer and training.

7. International Wildfire Incident Management System: A Proposal

As a result of severe fires over a number of years, national leaders have demanded a more coordinated approach to the management of wildfires, including receiving from or sending firefighting assistance to other countries. However, the ability to effectively cooperate between countries is still limited by organization and communication barriers. In the USA, State and Federal legislators, concerned at the lack of uniform emergency management protocols, directed federal, state, and local government to develop common incident management systems that provide a framework to enable wildland fire protection agencies to effectively facilitate clear response authority, acquire and mobilize resources, coordinate interagency actions, and provide effective management during incident response. A fundamental element of incident management was the creation of the “Incident Command System” (ICS), which provides standardization through consistent terminology and established organizational structures to enable effective, efficient incident management. Australia and New Zealand, faced with similar emergency response issues, evaluated incident management systems around the world, elected to adopt the ICS and modify it to meet their specific needs.

The complexity of incident management, coupled with the growing need for multi-agency and multi-functional involvement at incidents has increased the need for standard inter-agency incident management systems not only within a country/state but increasing internationally. Many countries have adopted similar or common systems of addressing emergencies. In addition a number have developed firefighting agreements based on a common system enabling interoperability when lending support to other countries. In the past this is usually to support adjoining States or Countries within the same geographical region. Since 2000 we have seen examples of this being broadened by support provision occurring from different hemispheres. In 2000 and 2002, Australia and New Zealand sent critically needed incident managers to the USA. Similarly early in 2003 the USA reciprocated sending fire specialists to Australia. Canada and the USA frequently exchange firefighting forces, especially along their borders. New

Zealand sent firefighting forces to Australia in 2002 and 2003.[46] ICS was also used during the wildland fire emergency in Ethiopia in 2000.[47]

The Incident Command System may need to be adapted to suit a particular country's existing political, administrative or cultural systems, customs and values. Where the primary purpose is to enhance emergency management within a country, such adaptations are not only beneficial, but may be essential to have the ICS system adopted. If the purpose of adopting ICS is to enhance cooperation between countries, through the sharing of resources such as fire management teams, it is highly recommended that the sending country and the receiving country both use the same emergency management system.

A strategic paper produced by the International Wildland Fire Summit in Sydney, Australia, 8 October 2003, suggested that such a system should be the ICS. Given that ICS is a proven model in many countries and given that training materials for ICS are freely available, there is considerable benefit to be gained by a country adopting this system.

It is proposed to introduce an International Wildfire Incident Management System (IWFMS) based on the incident management components discussed previously, including the principles of the ICS. This system would not necessarily require that specific components, such as ICS, be the incident management system of the country receiving or providing firefighting assistance. However, IWFMS components would need to be previously agreed upon, ideally in a formal Arrangement, and utilized by all countries cooperating in the wildfire emergencies.

IWFMS would also be considered as a candidate system to be introduced in the UN-driven process to strengthen the international system of responding to environmental emergencies. The UNEP and OCHA have established the international Advisory Group on Environmental Emergencies (AGEE) as their most important cooperation and support mechanism for the response to environmental disasters. The AGEE is an international forum that brings together environmental experts from around the world to share information, expertise and lessons learned for improved response to environmental emergencies worldwide, and in particular in

[46] See: International Arrangements on the Sharing of Wildland Fire Suppression Resources between the United States of America and Australia and New Zealand: http://www.fire.uni-freiburg.de/iffn/iffn_29/USA-Australia-NZ-Int-Arrangements.pdf

[47] See: The Ethiopia Fire Emergency between February and April 2000: http://www.fire.uni-freiburg.de/iffn/country/et/et_1.htm

developing countries. In 2007 AGEE founded the “Rosersberg Initiative”, which aims at strengthening the global regime that governs environmental emergency response and preparedness.[48]

The international firefighting assistance during the wildfire emergencies in Greece (2007, Russian Federation (2010) and Israel (2010) have revealed the need for introducing a unified incident management system, especially for the international deployment of aerial firefighting assets. Following the International Wildland Fire Summit (2003) an interest group was formed at the 4th International Wildland Fire Conference and recommended internationally concerted action.[49] In a series of International Aerial Firefighting Conferences (2008-2010) this idea consolidated.[50] In 2010 the International Fire Aviation Working Group (IFAWG) was founded and officially launched at the meeting of the UNISDR Global Wildland Fire Network / Wildland Fire Advisory Group at GFMC.[51] [52] The terms of reference have been laid down in the IFAWG Charter:

The “International Fire Aviation Working Group” (IFAWG) will work under the framework of the UNISDR Wildland Fire Advisory Group (WFAG) / UNISDR Global Wildland Fire Network (GWFN) as an advisory committee with the following principal objectives:

- Sharing of relevant information, especially information that will support the promotion and improvement of safety in the sector;
- Providing a conduit or facilitation mechanism for the sharing of resources between jurisdictions;
- Identifying of opportunities for harmonisation of operating practices and establishment of consistent standards, where appropriate; and recommend or initiate suitable harmonisation action, including the development of voluntary guidelines;
- Providing advice and guidance to nations and the United Nations regarding fire aviation through the UNISDR Wildland Fire Advisory Group / Global Wildland Fire Network.

48 http://ochaonline.un.org/ToolsServices/EmergencyRelief/EnvironmentalEmergenciesandtheJEU/RosersbergInitiative/tabid/2647/language/en-US/Default.aspx

49 http://www.fire.uni-freiburg.de/sevilla-2007/groups/Session-Aviation-Communique.pdf

50 See website of the last AFF Conference in Spain (December 2010), which includes the reports of all AFF conferences between 2008 and 2010: http://www.fire.uni-freiburg.de/course/meeting/2010/meet2010_19.htm

51 http://www.fire.uni-freiburg.de/GlobalNetworks/Joint-WFAG-FAWG-ILC-FMAA-Meeting-June-2010-Agenda-final.pdf

52 IFAWG website: http://www.ifawg.org/

8. Conclusions

The United Nations International Strategy for Disaster Reduction (UN-ISDR) and its Wildland Fire Advisory Group are working to assist and strengthen the efforts of United Nations bodies, other international organizations, and non-governmental organizations, and a large number of national agencies responsible for fire managements, to reduce the negative impacts of wildland fires and to promote safe, ecologically benign and environmentally safe concept of fire use in ecosystem management. Similarly, the UN-ISDR Global Wildland Fire Network (GWFN), the Global Fire Monitoring Center (GFMC) and the FAO are working systematically to increase the intra- and inter- regional cooperation in wildland fire management in the world. Consultations of the Regional Wildland Fire Networks in 2003-2010, expressed by the outcomes of the International Wildland Fire Summit of 2003 and the 4th International Wildland Fire Conference in 2007, revealed that the majority of countries worldwide is ready to establish and strengthen regional and international dialogues on cooperation and exchange of information, research and wildland fire management, including through agreements. It is hoped that the recommendations of this 5th International Wildland Fire Conference in South Africa will further contribute to this endeavor.

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Annex I

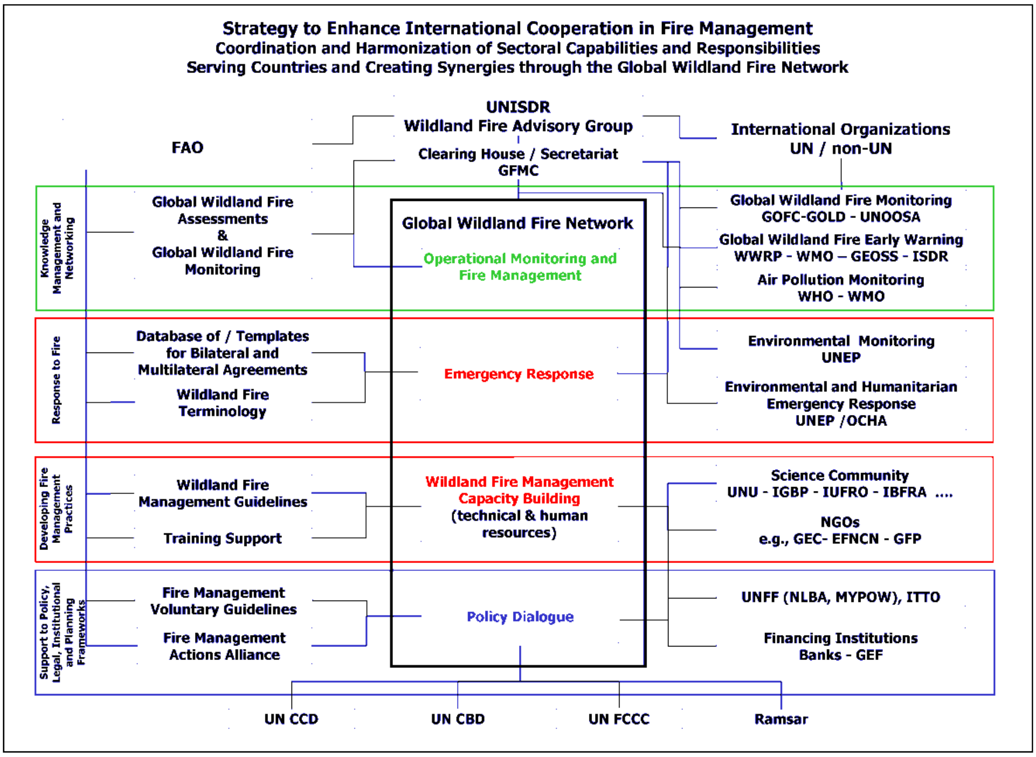

Figure 1. Overview of international organizations sharing responsibilities and tasks in global wildland fire management [53]

[53] Goldammer, J.G., 2006. Fire Management. Review of International Cooperation. FAO Fire Management Working Paper FM18, 45 p. http://www.fao.org/docrep/009/J9406E/J9406E00.htm

Annex II

At the 4th International Wildland Fire Conference (Sevilla, Spain, May 2007) the representatives of the Regional Wildland Fire Networks and the participants of the joint regional sessions agreed to the need to develop synergies through coordinated and collective action to address the most pressing problems related to fire management globally.[54] Further the conference participants recommended that:

- The international wildland fire community pursue the development of a global-scale international resource sharing strategy to assist countries with fire management planning activities (including prescribed fire for ecological purposes and fuels management), and active support during periods of wildland fire;
- The FAO promote the global adoption of Incident Command System (ICS) including the publishing of an annual list of countries which have implemented ICS;
- Regional strategies for fire management be developed and designed to the specific needs of regions;
- An international framework for fire management standards be developed and regional wildland fire training be supported, especially to meet the needs for capacity building in developing countries;
- Scientific research programmes addressing the consequences of changes of climate, land use and land cover, and socio-economic changes on fire regimes, environment and society must be supported at all levels;
- The Strategy to Enhance International Cooperation in Wildland Fire Management and the implementation of the Fire Management Voluntary Guidelines be encouraged and endorsed;
- Agencies and groups be encouraged to participate in the Fire Management Actions Alliance in support of their adoption of the Voluntary Guidelines;
- The UNISDR Global Wildland Fire Network, the Regional Wildland Fire Networks and the Secretariat of the global network, the Global Fire Monitoring Center (GFMC), be supported by national agencies and international donors aimed at fostering international cooperation in fire management, including collecting and disseminating fire information, arranging and enhancing international policy dialogue, and supporting projects;
- A series of Regional Consultations tentatively addressing "Global Change and Wildland Fire: Regional Solutions for Fire Management" – be held

[54] The results of the 4th International Wildland Fire Conference are documented at: http://www.fire.uni-freiburg.de/sevilla-2007.html

globally, within the next 1-2 years, to progress the global issues that are impacting people, resources and livelihoods;

- The 2nd International Wildland Fire Summit – tentatively addressing "Global Change and Wildland Fire: Fire Management Solutions for Mitigation and Adaptation" – be held within the next 2 to 4 years under the auspices of the United Nations and partners.

References

Note: Numerous references have been provided as footnotes or embedded in the text of this paper in order to facilitate online reading. Further search for documents on international cooperation in wildland fire management is facilitated by the search engine on the GFMC homepage (http://www.fire.uni-freiburg.de/). For searching documents only a relevant term (without adding "fire" etc.) needs to be entered.

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Wildland Fires and Human Security: Challenges for Fire Management in the 21st Century

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Abstract

Changes of fire regimes and an increasing vulnerability of humans to direct and secondary consequences of wildland fire are observed in many regions globally. Both increasing and decreasing intensity of land use are associated with set fires and often uncontrollable wildfire episodes. This was revealed by the fire emergencies in Bolivia and Russia in July-August 2010. Wildfires burning at the interface between wildlands, the fringes of suburbs, metropolitan agglomerations and rural settlements are increasingly impacting large populations, notably by extreme air pollution affecting human health and mortality. Other critical issues include wildfires burning on terrain contaminated by various types of hazardous chemicals (e.g. by mercury) and radioactivity. Remnants of military activities and armed conflicts, e.g. unexploded ordnance (UXO), depleted uranium ammunition and landmines are posing additional threats. Wildfires occurring in such contaminated terrain are resulting in secondary damages, such as chemical and radioactive air pollution and explosion of UXO and landmines on active or abandoned mined areas. Fires occurring during armed conflicts and causing collateral damages and fire purposely set as means of conflicts have been noted increasingly over the past decade. The Global Fire Monitoring Center (GFMC) has launched an initiative in 2008 to address challenges of fire management on contaminated terrain. This endeavour is supported by the Council of Europe and the Environment and Security Initiative (ENVSEC), an activity of UNDP, NATO, UNEP, OSCE and UNECE. Since 2008 the GFMC is publishing annual Global Wildland Fatalities reports.

Keywords: Wildfire, wildland fire, human security, radioactive contamination, chemical contamination, unexploded ordnance, land mines

1. Introduction

Observations and projections of zonal fire regimes reveal several major trends which imply that relationships between fire and the environment are going to change. There are some generally accepted major trends:

- Continuing excessive application of fire in land use and land-use change in the "former perhumid" equatorial rainforest belt, associated with extreme droughts that are attributed to regional climate change and seeming to be unprecedented since the beginning of recording of weather data in the late 19th Century, continue to contribute to extended wildfires, notably in impoverished / degraded vegetation;
- Wildfires are a major agent synergistic to and exacerbating the impacts of climate change (increase of severity and duration of dry spells, increasing aridity) and impacts of human activities (e.g., non-sustainable use of forest and non-forest lands). This is particularly the case in ecosystems subjected to "savannization" or steppe formation at the expense of forest / tree cover (throughout the paleo- and neotropical floral kingdoms and the Holarctic);
- Increasing occurrence of fire in global wetland and peat bog biomes due to cultivation / conversion involving drainage and fire use, and an increasing readiness of desiccated organic layers to burn as a consequence of extending vegetation periods, droughts and fire seasons;
- In the boreal zone interactions are expected between climate change, change of fire regimes and permafrost regimes, with consequences on species composition, habitability of permafrost lands for humans, and release of currently still trapped radiatively active paleogases.

The following section focuses on the cultural landscapes of the temperate-boreal Eurasian region where major trends are primarily influenced by human and cultural activities that are rather different from other regions of the world.[55]

2. Fire in the Cultural Landscapes of Temperate-Boreal Eurasia

In preparation of the first "Regional Forum on Cross-boundary Fire Management" in the region of the United Nations Economic Commission for Europe (UNECE) the Global Fire Monitoring Center (GFMC) provides rationale and arguments for developing a collective transnational view at recent socio-economic, political and land-use changes affecting fire regimes in temperate-boreal Eurasia.[56]

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[55] Note: An earlier version of this paper has been presented at the 5th International Wildland Fire Conference, South Africa, 9-13 May 2011.

[56] In preparation by the UNECE/FAO Teams of Specialists on Forest Fire and supported by the Council of Europe as a contribution to the "UN International Year of Forests" in 2011. Draft agenda: http://www.fire.uni-freiburg.de/intro/UNECE-Fire-Forum-2011-Draft-Agenda.pdf

Within the last decade temperate-boreal Eurasia has experienced a number wildfire episodes that have resulted in severe environmental damages, high economic losses and considerable humanitarian problems. This has prompted the United Nations Economic Commission for Europe (UNECE) to address recent socio-economic, political and land-use changes, as well as climate change, that are affecting fire regimes of temperate-boreal Eurasia.[57] The UNECE region, which is extending from Western Europe to Asia's Far East and spanning over more than 180 degrees longitude, is bearing a large variety of ecosystems and land-use systems. While specific causes and underlying reasons of extreme wildfires may be quite different throughout the region – there are many fire-related issues in common. For instance, in the Western Eurasian part of the region many neighboring countries are sharing similar natural, cultural and social conditions that are determining the occurrence and impacts of wildfires.

Besides changes that are evidently understood by the public there are hazards and risks that have been perceived only recently due to a better scientific understanding of the multiple impacts of fires, notably in the context of climate change and human health, but also with regards to an increasing vulnerability of society to direct and secondary effects of fire, e.g. in the context of fires burning at the interface of residential and industrial areas, or in terrain contaminated by industrial deposits or armed conflicts. Land-use change and heritages of former land use constitute a major driver of changing fire regimes in cultural landscapes of Eurasia.

The UNECE Forum therefore aims at analyzing the following recent developments in the region:

- Consequences of rural abandonment and urbanization on agriculture, pastoralism, forestry and wildfire hazard;
- Rural exodus affecting availability of rural work force, including availability of rural firefighters;
- Re-privatization of formerly nationalized forests resulting in vacuums of forest management in smallholder forest estates;
- Weakened governance over forestry and decreased fire management capabilities in many Eastern European and Central Asian countries as a consequence of

[57] "Regional Forum on Cross-boundary Fire Management" (United Nations Economic Commission for Europe – UNECE region), planned to be held at the United Nations in Geneva in early 2012, coordinated by the Global Fire Monitoring Center (GFMC) and the UNECE/FAO Team of Specialists on Forest Fire, and supported by the Council of Europe.

the transition of national economies, resulting in uncontrolled or illegal forest use and increase of related wildfires;

- Increasing problems of wildfires affecting the perimeters of metropolitan areas, settlements and developments dispersedly located in wildlands;
- New standards for reducing gaseous and particle emissions from fossil fuel, biofuel and other open burning that are affecting human health;
- Concerns about the impacts of radiatively active trace gases and particle emissions from vegetation fires affecting the functioning of the atmosphere and of ecosystem, e.g. the consequences of the transport of fire-emitted black carbon to the arctic environment;
- Vulnerability of society to fire-generated air pollution, new scientific insights in the impact of fire emissions on human health;
- Resulting new conflicts in fire management, e.g., controversial views on the acceptance of prescribed burning;
- Secondary problems associated with wildfires, notable on territories contaminated by radioactivity and remnants from armed conflicts (e.g., unexploded ordnance, land mines, uranium-depleted ammunition);
- Consequences of climate change on cultural fire regimes and ecosystem vulnerability, e.g. transformation of former fire-excluded or -protected ecosystems or land-use systems such as peat bogs and other organic terrain, or high-altitude mountain ecosystems, such as in the European Alps.

On the other hand there is an increasing perception by the public and by policy makers to review and adopt innovative integrated fire management solutions and to exploit of the results of successfully completed international fire research projects in Eurasia for developing adequate public policies affecting fire management and operational fire management.

Indeed, the recently published White Paper on Use of Prescribed Fire in Land Management, Nature Conservation and Forestry in Temperate-Boreal Eurasia (Goldammer, 2010a) reveals that the use of fire – including historic swidden (shifting) agriculture, and other disturbances by land cultivation – have contributed to shape landscape patterns of high-value ecological and cultural diversity in large parts of temperate-boreal Eurasia, e.g. heathlands, open grasslands and meadows. In the eastern Euro-Siberian biota, e.g. in the light taiga, natural fires have shaped open and stress-resilient forest ecosystems (Sannikov and Goldammer, 1993).

The rapid socio-economic changes in the past four decades and the recently increasing trend of rural exodus all over Eurasia, however, have resulted in abandonment of traditional land-use methods (Dimitrakopoulos and Mitsopoulos, 2005). With the elimination of these disturbances by cultivation, including traditional burning practices, large areas of Europe are converting to fallow lands, a process that is associated with ecological succession towards brush cover and forest, and an overall loss of open habitats. Besides the loss of valuable biodiversity the abandoned lands constitute an increase of wildfire hazard – a trend that is revealed by a growing number of extremely severe fire disasters. Similarly, the exclusion of fire in natural ecosystems such as northern boreal and sub-boreal coniferous forests in Eurasia has resulted in changing vegetation composition and an increase of wildfire hazard, notably in Central-Eastern Eurasia.

Changing paradigms in ecology and nature conservation recently have led to reconsidering fire-exclusion policies in certain sectors of land / landscape management, nature conservation and forestry. However, the use of prescribed fire in ecosystem management in Europe may not exclusively target those vegetation types that have been shaped by fire over historic time scales, but to introduce fire as a tool to substitute abandoned cultivation practices (Goldammer, 2010a).

A sound understanding of the “pros and cons” of prescribed fire application is necessary as well as the consideration of side effects of fire use. Large areas threatened by land abandonment are embedded in industrialized regions in which society is becoming increasingly unreceptive to fire emissions – the fire and smoke episode in Western Russia in 2010 is a striking example for this increased vulnerability (Goldammer, 2010b). Legal restrictions for open burning must be understood in the context of clean-air rules and the need for reducing gaseous and particle emissions that are threatening human health (cf. chapter 18 of this volume). The concerns of those considering prescribed fire emissions a contribution to the increase of the anthropogenic greenhouse effect and thus global warming is mixing in this debate. Here is where new approaches and terminologies are developing, e.g. the critical review of “necessary” and “unnecessary” burning in the agricultural domain in northern Eurasia.[58]

On the other side it is noted that nature conservation agencies, non-government actors and the general public meanwhile have a rather sound and better understanding and perception of the “nature of fire” as compared to the situation two to three decades ago. International (regional) dedicated networks

[58] The *International Conference on Open Burning and the Arctic* (Russia, November 2010), which explored the impacts of emissions from open fires on Arctic climate, particularly black carbon emissions from set fires in Northern Eurasia, provide a critical view of the escalating fire use in the agricultural sector (cf. Clean Air Task Force (CATF) [2009]).

and research projects such as the Eurasian Fire in Nature Conservation Network (EFNCN)[59], within which the White Paper on Use of Prescribed Fire was developed, and particularly the European Integrated Project "Fire Paradox", significantly contributed to the acceptance of fire use in wildfire hazard reduction and fire suppression (Sande Silva et al., 2010; see also Birot, 2009).

3. Recently Emerging Fire Threats in Eurasia

The Eurasian region is experiencing a range of fire problems that are an expression of heritages and recent changes in the cultural landscapes. Some examples are given in the following.

Armed Conflicts

Fires occurring during or after armed conflicts or during political unrest constitute a major humanitarian and security issue. The history of fire use as a weapon during wars is as long as the history of armed conflicts of humankind (Pyne, 1995). Most recent occurrence of wildfire during armed conflicts, however, cannot clearly be assigned to intentional tactical or strategic purposes. Most of the fires highlighted in the following are rather collateral damages during conflicts, or fires that were otherwise started at times of armed conflict. Conflict parties often used wildfires as opportunity and reason for mutual accusations. The most recent conflict-related wildfires occurred mainly in the South Caucasus, Near East and the Central Asian Hindu Kush regions.

Nagorno-Karabakh (2006)

During the period of June to September 2006, extended wildfires affected territories situated close to the Line of Contact (LoC) in and around the Nagorno-Karabakh region. Countries involved in the unresolved conflict around Nagorno-Karabakh accused each other to have started the fires intentionally. The fires affected large areas of abandoned lands around the LoC and adjoining agricultural and forest lands. Impediments to control the fires included the threat of landmines and unexploded ordnance in the area affected by fires, as well as the general tensions between armed forces along the LoC. Concerns over the fires in the affected territories resulted in the UN General Assembly Resolution A/RES/60/285

[59] http://www.fire.uni-freiburg.de/programmes/natcon/natcon.htm

"The Situation in the Occupied Territories of Azerbaijan" (15 September 2006).[60] The Organization for Security and Cooperation in Europe (OSCE), with the technical assistance of the United Nations Environment Programme (UNEP) and the Global Fire Monitoring Center (GFMC), assessed the short-term and long-term impacts of the fires on the environment. In his report to the UNGA the OSCE Chairman-in-Office recommended a number of short- to long-term measures aimed at improving fire management capability in the countries concerned and to contribute to peace building in the region (UN General Assembly, 2007).[61] Between 2007 and 2011 the recommendations were implemented by the GFMC using funding of the Environment and Security (ENVSEC) programme and the Euro-Mediterranean Major Hazards Agreement (EUR-OPA) of the Council of Europe.

Afghanistan / Pakistan (2006)

In 2006 the armed conflict in the border region between Afghanistan and Pakistan escalated. Afghanistan-based NATO forces entered Pakistan's airspace from the neighboring Nooristan province. The air raids on two border villages Daroshot and Azo (Arandu) involved dropping of bombs, which ignited wildfires in the surrounding forests of the area.[62]

Israel-Lebanon (2006)

During the armed conflict shelling, air raids and rocket attacks started numerous fires on the territories of Israel and Lebanon at a time of drought and extreme wildfire risk (Achiron-Frumkin and Frumkin, 2006). In Israel 800 forest fires were induced by rockets (400 of these wildfires required response) affecting 1,200 ha of forests (mainly coniferous). In addition about 6,600 ha of nature reserves and national parks, and of open landscapes proposed for conservation as nature reserves, as well as ca. 7,000 ha pasture lands were burned. In Lebanon the total area of burned forests was 712.5 ha and that of burned productive trees was 308.8 ha.[63]

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60 UNGA Resolution A/RES/60/285 "The Situation in the Occupied Territories of Azerbaijan": http://www.fire.uni-freiburg.de/GlobalNetworks/SEEurope/UNGA%20Resolution%207%20September.pdf

61 61st UN General Assembly Session, Agenda item 17 "The situation in the occupied territories of Azerbaijan", Letter dated 20 December 2006 from the Permanent Representative of Belgium to the United Nations addressed to the Secretary-General: http://www.fire.uni-freiburg.de/GlobalNetworks/SEEurope/N0720860-OSCE-UNGA-ENG.pdf

62 http://www.fire.uni-freiburg.de/media/2006/10/news_20061019_pak.htm

63 Report of Association for Forests, Development and Conservation (AFDC) made available to and archived at GFMC

Georgia (2008)

During the armed conflict in Georgia in August 2008 a number of forest fires occurred as a consequence of military activities in several sites of the country. According to reports by government authorities and non-government organizations the fires burned between 13 August and end of August 2008 (Ateni Gorge and Borjomi Gorge). Several fires affected also two national parks and one nature reserve. Three fires burned within the Borjomi-Kharaguali National Park. A joint mission of OSCE and UNEP to assess the environmental impacts of the conflict in Georgia confirmed the collateral damages caused by fires in Borjomi Gorge and noted that additional areas had burned along the main corridors of combat activities (roads between South Ossetia and Gori Region).[64]

Wildfires and Land Mines

The countries in the region most affected by land mines are Bosnia and Herzegovina, Croatia, Serbia, Macedonia, Georgia, Ukraine, and Armenia. The origin of the land mines and unexploded ordnance (UXO) in Bosnia and Herzegovina, Croatia and Serbia is from the civil war from the last decade of 20th century. It is estimated that about 300,000 ha are contaminated by land mines and UXO (mostly along to the line of conflict during the civil war). According to a report from Bosnia and Herzegovina about 127,000 ha of forests or ca. 10% of the total forest cover are contaminated by UXO and land mines (Pešković, 2008). Croatia reports 95,000 ha mined forests and other lands with total of ca. 100,000 land mines left (Jungwirth, 2009). This is a significant problem and challenge for forest fire management since wildfires burning on mined lands cannot be fought on the ground using conventional equipment. Wildfires triggering explosions of land mines have caused casualties in several cases and resulted also in reluctance to attack wildfires, or in orders fire services to stay out of the “red zones”.

Similar reports from the Line of Contact (LoC) between India-Pakistan in Jammu and Kashmir reveal that landmines are the main hindrance in controlling forest fires, e.g. the incidences in July and December 2009 when a number of landmines laid along the LoC exploded during the wildfire.[65] In Israel wildfires in

[64] Report of the Joint OSCE / UNEP Environmental Assessment mission to Georgia (29 September to 3 October 2008): http://www.fire.uni-freiburg.de/GlobalNetworks/SEEurope/OSCE-UNEP-GFMC-Env-Assessment-Georgia-Oct-2008-OSCE-34577_en.pdf

[65] Landmines explode, hamper efforts to put out spreading LoC forest fires”, published on 9 July 2009 by www.kashmirlive.com and http://www.fire.uni-freiburg.de/media/2009/07/news_20090710_in.htm; “Bushfire sets off 6 landmines in Poonch”, published on 13 December 2009 by Rising Kashmir: http://www.risingkashmir.com/index.php?option=com_content&task=view&id=19095&Itemid=1

minefields on the Golan Heights threatening a UN peacekeeping battalion in August 2009.[66]

Unexploded Ordnance (UXO)

Unexploded Ordnance (UXO) is found on several hundred thousand hectares of forests and other lands throughout Western, Eastern and Southeastern Europe. Remnants of World War I battles along the frontlines of 1917 in Southern Macedonia have repeatedly created problems, e.g. during the fire season of 2007 when more than 70 incidents of explosions of ammunition triggered by forest fires were noted (Goldammer and Nikolov, 2007). In Germany, the battlegrounds of the final phase of World War II in Brandenburg State around Berlin are still highly contaminated by unexploded artillery grenades and bombs. In addition, former and active military exercise areas and shooting ranges, with some of them dating back to the early 1900s, some established after World War II, are posing high risk to civilian populations and especially firefighters (Goldammer, 2010; Goldammer et al., 2009a). A recent estimate reveals that ca. 250,000 ha of former and active military training and shooting ranges in Germany are contaminated by UXO.[67] Besides the above-mentioned land mine contamination in the Balkans and the South Caucasus the combat grounds in and around the Nagorno-Karabakh territory represent one of the major UXO-polluted terrains worldwide.[68] In the Near East the aftermath of the Israel-Lebanon War of 2006 brought problems with unexploded cluster bombs.[69]

Threats arising from Wildfires Affecting other Military Assets

Wildfires affecting other military assets include ammunition depots, nuclear and conventional research facilities and storage facilities, and active military shooting and exercise ranges. Forest fires entering ammunition storage facilities in the territories of the former Soviet Union in recent years. In 2008 artillery shells and other ammunition at a storage facility in Ukraine, exploded when a forest fire swept into the depot. Details of the causes of some of other reported incidents remain unclear, e.g. a fire and explosions at a munitions depot in southern Ukraine in 2004 in which five people were killed, and a fire at a Soviet-era military base in

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[66] "Feueralarm: Grasbrände in der Zone", published on 3 August 2009 by the Austrian Army http://www.bundesheer.at/ausle/undof/artikel.php?id=2893

[67] This assessment of January 2011 has been extracted from the databank "Nature Conservation and Military", David Foundation, Germany (unpublished data on file at GFMC).

[68] c.f. footnote no. 8.

[69] c.f. footnote no. 10.

Kagan, Uzbekistan, which spread to an ammunitions depot in July 2008, igniting a series of explosions that killed three people and injured 21 others; or the fire burning an arsenal near Ulyanovsk in November 2009.

During the fire and smoke pollution episode in Western Russia in July/ August 2010 several military depots and nuclear facilities were threatened by fire. In the first week of August wildfires overrun a weapons storage facility near Moscow (the Central Air and Technical Naval Base 2512), with an estimated loss of 200 airplanes and half of the buildings of the base destroyed. At the same time the Russian military garrison Naro-Fominsk near Moscow moved all its artillery ammunition and rockets to a safer location as wildfires advanced in the region. In the same week wildfires threatened a factory in Kolomna that produced guided missiles, the Novovoronez nuclear power station near Voronez and the Tryokhgorny nuclear closed city in the Urals (Soviet code name: Zlatoust-36) where nuclear warheads are assembled and dismantled. A critical situation developed in the closed „nuclear city“ of Sarov (Arzamas-16) where wildfires advanced towards nuclear arms producing facilities.[70]

4. Emissions from Fires Burning on Contaminated Terrain

In some countries forests and other lands are contaminated by various types of hazardous chemical and radioactive pollution. Wildfires occurring in such contaminated terrain may result in secondary air pollution. The territories most affected by radioactive pollution have been contaminated by the release of radionuclides during the failure of the Reactor Number Four of the Chernobyl Nuclear Power Plant in 1986. Among the total are of 6 million ha of radioactively contaminated terrain in Ukraine, Belarus and Russia the most polluted forest area covers over 2 million ha in the Gomel and Mogilev regions of Belarus, the Kiev region of Ukraine, and the Bryansk region of the Russian Federation. The main contaminator was found to be caesium-137 (^{137}Cs); in the core zones of contamination, strontium-90 (^{90}Sr) and plutonium-239 (^{239}Pu) were found in high concentrations. Generally, under average dry conditions, the surface fuels contaminated by radionuclides – the grass layer and the surface layer of peatlands – are consumed by fire. Most critical is the situation in peat layers, where the radionuclides are deposited. The long-range transport of radionuclides lifted in the smoke plumes of wildfires and their fallout on large areas were investigated in

[70] Data of this section on file at GFMC: For a detailed situation description and a map of Sarov and surroundings, with active fires, see: http://www.fire.uni-freiburg.de/GFMCnew/2010/08/07/20100807_ru.htm

detail in 1992 (c.f. review by Goldammer et al., 2009b). A recent study presented at the conference "Twenty-Five Years after Chernobyl Accident: Safety for the Future" (Kiev, Ukraine, 20-22 April 2011) concluded that radioactive fallout from a large forest fire occurring in the Chernobyl Exclusion Zone could affect the food chain and thus be considered threat to human health and security (Oliver et al., 2011; Zibtsev et al. 2011).

Recent research reveals that, as a consequence of climate change, mercury deposits once protected in cold northern forests and wetlands will increasingly become exposed to burning. Mercury is released to the atmosphere with fire smoke. Turetsky et al. (2006) quantified organic soil mercury stocks and burned areas across western boreal Canada; it was assumed that, based on ongoing and projected increases in boreal wildfire activity due to climate change, atmospheric mercury emissions will increase and contribute to the anthropogenic alteration of the global mercury cycle and to the exacerbating mercury toxicities for northern food chains.

According to a study by Genualdi (2008) vegetation fires have the potential to release toxic industrial and agricultural pollutants previously deposited in ecosystems over the decades, lifted by fire and transported with smoke particles.[71] In the case of pesticides and polychlorinated biphenyls, or PCBs, these persistent organic pollutants can land in regions where the compounds are now banned – or even in the Arctic, where they were never used. One of the studies looked at the long-range transport from Siberia by using satellite imaging of smoke plumes and modeling of air mass trajectories which allowed to track the source of pollutants emitted by Siberian wildland fires in 2003 and transported to the Pacific Northwest of the U.S., e.g. dieldrin and alpha-hexachlorocyclohexane (alpha-HCH).

5. Conclusions and Outlook

This brief overview paper has highlighted selected wildfire threats in the Eurasian space that are affecting human security. The aspects of vegetation fire smoke impacts on human health been covered elsewhere in detail (e.g., Goldammer et al., 2009b). Besides extended fire smoke episodes in South East Asia and South America, especially in Bolivia and Brazil in 2010 and previous

[71] See also summary report "Forest fires could spread pollutants", released by www.usnews.com on 3 December 2009, available at GFMC repository: http://www.fire.uni-freiburg.de/media/2009/12/news_20091204_us2.htm.

years, it should be noted that the heat wave and wildfire smoke episode in Western Russia in July and August 2010 resulted in about 55,800 additional (above long-years average) deaths. These fatalities are attributed to premature deaths as a consequence of both the extreme heat and extended fire smoke pollution.[72]

Furthermore the annual global wildland fire fatalities reports should be noted that are published by GFMC since 2008.[73] The reports reveal that 345, 374 and about 386 people were killed directly by wildfires in 2008, 2009 and 2010 respectively (2010 number without the above-mentioned 55,800 premature deaths in Russia attributed to heat wave and fire smoke pollution).

In conclusion it is stated that wildfires in the cultural and industrial landscapes of Eurasia are a significant threat to human security. Society in this region of the world is becoming increasingly vulnerable to wildfire – a trend that needs to be taken into account when addressing the underlying causes for an increased fire hazard and fire risk in this part of the world.

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[73] http://www.fire.uni-freiburg.de/media/bulletin_news.htm

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ORAL PRESENTATION I

Forest Fires and Management in China

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Abstract

Since 1987, the government attaches great importance to fire management. But there are still many fires occurrence in China every year. For the period 200-2009, the yearly average fires were 9,493, which caused burned areas 333,796 ha. The yearly cost of fighting fires was 171,220,000 RMB (about 26,341,538 US$). Human activities were mainly attributable to the forest fire, occupying more than 98%. Most forest fires occurred in spring and autumn. Most fires occurred in southern China, accounting for 52% of the total each year, 37% in the southwest, 6% in northwest, and 4% in northeast and inner Mongolia, and 1% in other areas. It is expected the average temperature in northeastern China could increase 2.22°C in scenario A2 and 2.55°C in the 2040s in scenario B2. That may cause the potential burned area will increase by an average 3% and 20% in 2040s under scenario A2 and B2, respectively. The fire season will prolong on average by five days and 18 days in the 2040s under scenario A2 and B2, respectively. Measures were made for reducing the fires, such as improving the organization system, fire equipments, strengthening fire monitoring and developing the fire research, ect.

INTRODUCTION

Fire plays an important role in forest ecosystem. After the great fires occurred in 1987 in northeastern China, the government pays more attention to the fire management. The fire agencies were founded in local government at all levels. The measures were made on fire prevention and extinguishment. From 1988 till now, statistics show that the average number of forest fire is 7,935, and the affected forest area is 92,000 hectares. Chinese government attaches great importance to forest cultivation and prevention, especially grasps the intensification of prevention of forest fire as an important measure of the construction of the ecological and forestry prevention.

CAUSES OF FOREST FIRES

Hunan's activities

Most fires are due to man's fault while inappropriately using fires in production and daily life. According to statistical analysis for 2001-2010, human activities were mainly attributable to the forest fire, occupying more than 98%. Take 2010 for instance, charcoaling, burning paper as sacrificial offerings, smoking in forest areas, or fires caused by children and the mentally handicapped account for 34.1%, 18.1%, 5.9%, 4.3%, and 3.5% respectively. In Daxing’anling, northeastern China, the lightning fires accounted for about 30%. In southwestern and southern China, many fire caused from prescribed fires in farmland. In Northeast China, hunter's casual smoking and cooking fires by medical herb pickers or mushroom pickers often cause forest fires.

FIRES DISTRIBUTION

Fire peak seasons

The occurrence of forest fires in China showed two peaks in a year (Fig. 1). In northern China, the fire season includes two periods, which are spring (from March to June) and autumn (from September to November). But in southern China, most fire occurred in dry season (from November to next May). In general, there are two peaks of fire occurrences. For example, in 2005 the most fires occurred in April (4,604 ha, 40%), and the most burned areas in October (128,662 ha, 40%) (Fig 1).

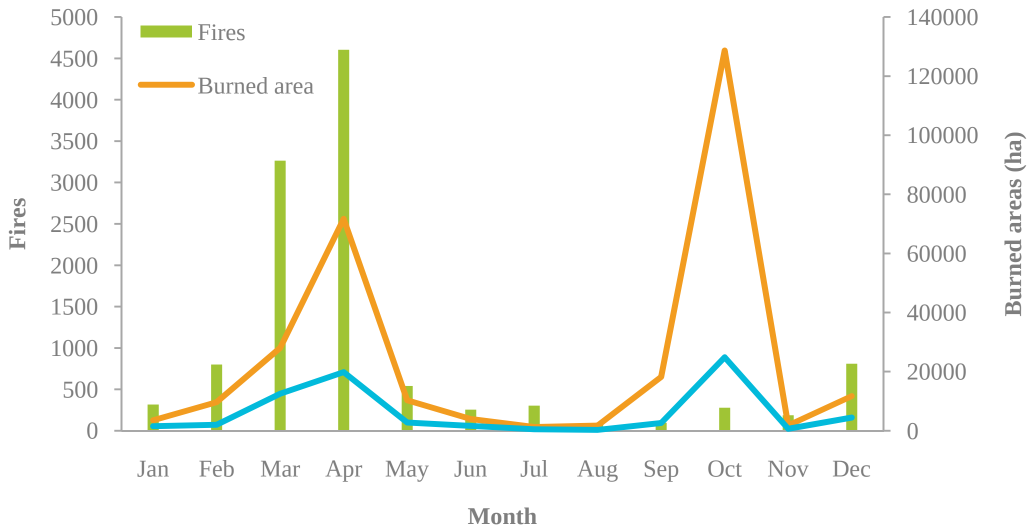

Fig. 1. Fire occurrences by month in 2005

Regional distribution

Most fires occurred in Southern forest, accounting for 52% of the total each year, 37% in the southwest, 6% in northwest, and 4% in northeast and inner Mongolia, and 1% in other areas. For example, in 2005 the Hunan province had most fires (3,204 fires, accounted for 28% of the country) and Heilongjiang had most burned areas (132,248 ha, 46%) and burned forests (24,307 ha, 33%) (Fig. 2).

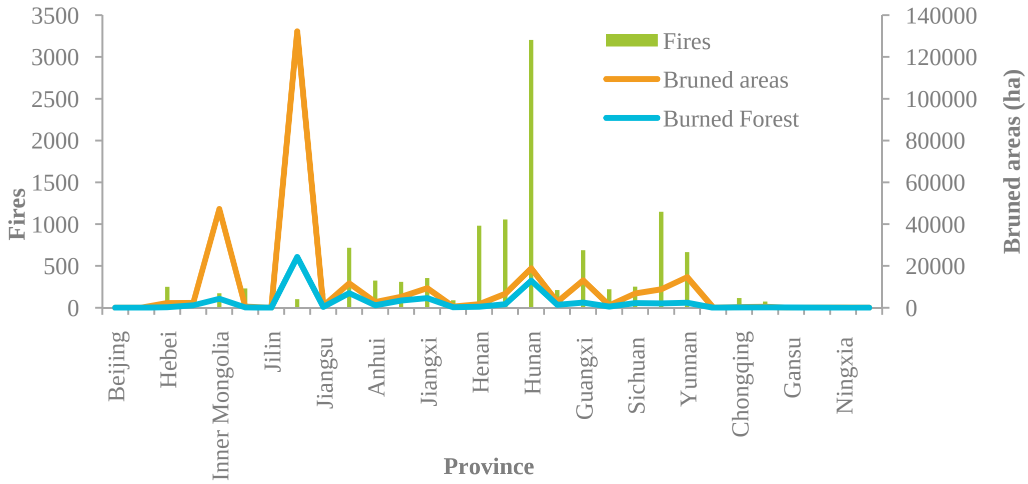

Fig. 2. Fires distribution in provinces in 2005

RECENTLY FIRE SITUATION

For the period 200-2009, the yearly average fires was 9,493, in which fire alarm (< 1ha), average fire (1-100 ha), big fire (100-1000 ha) and conflagration (>1000 ha) were 5452 (57%), 4014 (42%), 23 (0.2%) and 4 (0.04%), respectively. The fires caused burned areas 333,796 ha in each year, in which 138,712 ha (42 %) was occupied by forests. In the period, the most burned areas occurred in 2003 (1,123,751 ha) and most fires (14,144) in 2008 (Fig 3).

The yearly cost of fighting fires was 171,220,000 RMB (about 26,341,538 US$), and brought the other losses 131,257,500 RMB (20,193,460 US$). Meanwhile, the wildfires caused 69 people died and 68 wounded in each year.

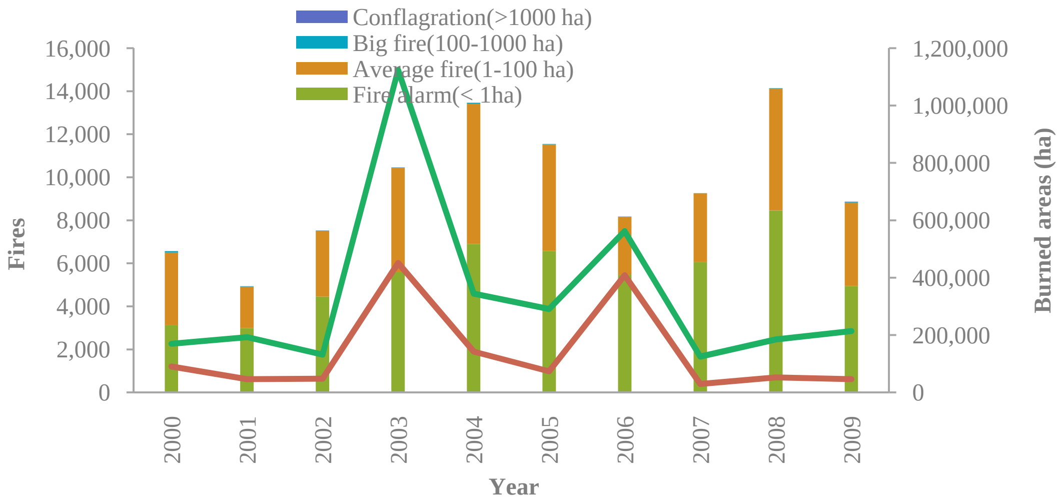

Fig. 3. Fires occurences burned areas in China for 2000-2009

EXPECTED FIRES IN THE FUTURE UNDER CLIMATE CHANGE

Climate change in 2040s (2041-2050)

Temperature and precipitation are two important factors affecting climate, which inevitably become the factors of greatest concern in the analysis of future climate changes. In the baseline period (1961-1990) the average annual temperature of the northeastern China was 1.7°C and annual precipitation 505.1 mm. Precipitation is mainly concentrated in the period from June to September (accounting for 76.3%) and accounted for 14.9 and 4.6% of annual total precipitation in the spring and autumn fire seasons. During the baseline period the observed average temperature in the peak of the spring fire season (from March to May) was 3.2°C (ranging from –8.2−10.5°C) and the average monthly precipitation was 23.7 mm (ranging from 4.5−68.4 mm).

The average temperature in northeastern China could increase 2.22°C (ranging from 1.13 to 3.51°C) in scenario A2 and 2.55°C (ranging from 1.35 to 3.39°C) in the 2040s in scenario B2, which are significantly larger than those in the rest of the country (Tian et al., 2011). The annual precipitation of northeastern China could increase 55.9 and 5.0 mm in the 2040s under scenarios A2 and B2 respectively. The mean relative humidity shows a small change and wind speed is expected to decrease slightly. The average relative humidity could increase 0.17% and –0.90% in the 2040s under both scenarios and wind speed could change by –0.04 and –0.09 $m \cdot s^{-1}$.

Changes in potential burned areas

During fire seasons the average monthly temperature could significantly increase in the 2040s under scenarios A2 and B2. Under the two scenarios, precipitation in June and October could be significantly reduced by 4.2 mm (5%) and 5.0 mm (6%), suggesting that the drought trend occurring in early summer and autumn would lead to increased fire risk.

The FWI system is correlated with the area burned and the ratio of FWI is a better index to reflect the relationship between fire danger and potential burned areas. Approximately a 1 to 1 relationship between FWI and area burned has been suggested, based on statistical data of several decades (Harrington et al., 1983; Wittrock & Wheaton, 1997). For example, if the FWI were to increase by 50% for a scenario simulation we could expect a similar increase in area burned (Flannigan et al., 2001). Under scenario A2, the average FWI ratio is 1.03 in the 2040s, which in March, April, May and October are expected to be 0.88, 1.09, 1.08 and 1.07 respectively. This suggest that potential burned areas are expected a decrease slightly in March and increase in the other months. During the spring fire season the central region of Heilongjiang shows a high FWI ratio, and burned areas with high FWI ratios are expected to expand significantly in October, in Jilin, southern Liaoning and northern Heilongjiang (Tian et al., 2011).

Under scenario B2, the average FWI ratio is 1.21, which suggests that the potential burned area could increase by an average 20% in the 2040s. The FWI ratios in March, April, May and October are 1.21, 1.22, 1.05 and 1.36 respectively. October is the month with the most significant change in the FWI ratio. In March and April the FWI ratios are higher in the east and in May in the central regions of Heilongjiang. In October potential burned areas increased are mainly found in southeastern parts, i.e., Heilongjiang, eastern Jilin and southern Liaoning.

Changes in length of fire season

Compared with the baseline period, under scenarios A2 and B2, the number of days with high, very high and extreme fire danger ratings will increase, while the length of the high fire danger rating season increase is expected to increase significantly under scenario B2. Under scenario A2, the number of days with high, very high and extreme fire danger ratings will increase on average by five days in the 2040s, during which the number of days of high, very high and extreme fire danger rating will increase by 0, 2 and 3 days respectively (Tian et al., 2011). The number of days of high fire danger ratings will increase significantly in the east, while the length of the fire season will decrease in most of the west. Compared with the baseline period (1961-1990), the fire season could be prolonged by 18 days in the 2040s under scenario B2, during which the number of days of high, very high and extreme fire danger ratings could increase by 3, 7 and 8 days, respectively. The length of the fire season could increase in most of northeast, but significantly in the center.

EFFORTS TO REDUCE THE FIRES

Effective measures are adopted to enhance the management of forest fire control, and minimize the number and losses of forest fires.

Laws and regulations

Since 2004, the Chinese central government has issued a series of documents, schemes, and regulations. Such as “Notification From the State Council on Further Implementing the Forest Fire Prevention”, “State Emergency Preplan on Handling Particularly Serious Forest Fires”, and “Forest Fire Regulations”. These drafts and regulations greatly enhanced the scientificity and standardization of forest fire prevention career in China.

Organization system

At present, China government sets up the National Forest Fire Prevention office, which is composed of 19 member organizations. State council also holds meeting to deploy forest fire management. Officials of governments at all levels take their own responsibilities. Till 2010, 3326 forest fire command headquarters with 63,000 member staff and 3544 administrative offices with 20,000 member staff have been built in China. There are fire agencies in the government at all levels.

Fire sources management and education

Fire sources were strictly controlled in key forest regions. Personals entering woodlands need to be checked and notified the fire sources management in the region. Billboards and posters are located in places. Broadcast, TVs, magazines, and networks were fully used to publicize the importance of forest fire prevention in key forest regions. So the public's awareness of the importance of fire prevention has been reinforced in past twenty years.

Fire monitoring

In China, the satellites and airplanes were used in fire detection except monitoring on the ground. There are 18 air bases in northeastern and southwestern China used in fire season. Each year more than 70 aircraft are rented, including more than 40 helicopters. Many satellites were used in fire season for fire detection, such as FY-1C, FY-1D, NOAA Series (NOAA-12, NOAA-14, NOAA-15, NOAA-16, NOAA-17), EOS/MODIS (terra, aqua).

Fire equipments

There are 16,000 forest fire brigades in the whole country, which include 510,000 fire fighters. There also exists a forest armed police army (more than 10,000 in total). Since 2006, the central government has invested 2.6 billion RMB for fire prevention construction work. Over 200 projects were developed in key forest region to reduce the fire danger by using the comprehensive measures. So the infrastructures and facilities in high-risk environments and key point's areas are greatly improved. Funds on forest fire prevention and fighting are also included in the government budgets. Those were built of 16,000 fire watchtowers, 1,310,000 km highways, 1,190,000 km fire belts or fuel breaks. 63,000 special vehicles and 6700,000 fire machinery are equipped. There are 3 state-owned warehouses and 11,000 regional warehouses. More than 100 air-bombers are used in distinguishing fires in 15 provinces, flying more than 10,000 hours annually.

Fire danger rating system

A national fire danger rating system are founding and a net of fire weather stations will finish for better monitoring the fire danger. Some research projects are progressing on basic fire sciences and technologies application.

CONCLUSION

Although the government made great efforts on fire management, the serious fire situation is still a problem faced by the government. Most fires are caused by human activities. It is expected the average temperature will increase in most areas of China, and the potential burned area also increase in the future under the climate change scenarios. Measures should be made on fire prevention, monitoring, and fire fighting.

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The Report of Forest Fire Organization, System and Skill in Korea

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Abstract

In this study, we studied and analyzed the change of forest fire policies in order for helping to improve a established forest fire policies. We divided into 7 periods for easier analysis. The first period was 'the period of pre-establishing the Korea forest service after independence (1945-1966). And the second was 'the period of pre-basic plan of forest' after establishing the Korea forest service(1967-1972). The third was 'the period of the first basic plan of forest'(1973-1978). The forth was 'the period of the second basic plan of forest'(1979-1987). The fifth was 'the period of the third basic plan of forest'(1988-1997). The sixth was 'the period of the forth basic plan of forest'(1998-2007). And the seventh was 'the period of the fifth basic plan of forest'(2008-th present).

In the result, the fire fighting organization, system and techniques was made rapid progress after Goseong forest fire in Kangwon region in April 1996. For future large scale forest fire attacking, the establishment of more systematical regional forest fire action plan and exercise from this would be needed.

Introduction

This study was surveyed in 2010 when it was the 50th anniversary of forest fire statistics starting. Therefore, we analyzed forest fire statistics during 50 years and policy for making an alternative proposal and for preparing the new policy under future climate change condition. In this process, we classified the change of organization, system and skill relating forest fire by several periods.

Methodology

For analyzing Korea forest fire policy from 1945 to 2010 and proposing an alternative plan, we researched the diversity literature on forest fire like‘1996 Goseong forest fire white paper’, ‘2000 eastern coastal region forest fire white paper’, ‘2005 Yang Yang forest fire white paper’ ‘50 years of Korean forestry policy’, ‘The comprehensive countermeasures for forest fire prevention’, ‘The forest fire statistics’, ‘The footprint of forest fire administration during 20 years’and etc.

Results and Discussion

1. The period of pre-establishing the Korea forest service after independence (1945-1966)

In this period, the service of forest fire prevention and attack was mainly controlled by the fire department, the bureau of public order in the Ministry of home affairs ‘The temporary special law for forest protection’ was legislated for decrease in forest fire in 1952. The skill for forest fire prevention in this period was the organization of the forest fire guard which was composed up officers of local government and members of a forestry association. The guard attacked forest fires using agricultural implements.

2. The period of pre-basic plan of forest after establishing the Korea forest service (1967-1972)

The Koreat forest service was established in Jan. 1967. The main policy in this period was ‘the know-how of forest fire attack’ written in 1968 and ‘the handbook for forest fire guarding and prevention’ was proclaimed in 1971. And the forest aviation headquarters was inaugurated in this period. This meant that the air attack was started. For improving of attack efficiency, the forest fire attack equipment like a forest fire rake and a forest fire cleaner was distributed. The surveillance and attack was performed according to handbook.

<A banner about forest protection in 1960s>

<The watchtower for forest fire observation>

<The forest fire attack by local residents>

3. The period of the first basic plan of forest (1973-1978)

The forest fire warning system was reinforced in this period. The measure for forest fire prevention was classified by 3 stages (prevention, attack and restoration). The restrict policy of entering mountain was implemented in 1973 and the system of forest protection liabilities was modified and improved in 1975. In this period, the helicopter was introduced for attack, but, the public were mobilized in general forest fire attack.

4. The period of the second basic plan of forest (1979-1987)

In this period, the early warning system according to weather condition was introduced. The law for the restricted area designation of a mountain entrance was legislated in 1980. The term for forest fire prevention was designated legally. The air attack using helicopter was operated for the first time and the efficiency of attack was improved by changing to mechanical equipment in this period.


<The first air attack using helicopter (Hughes 500D, 1981)>

5. The period of the third basic plan of forest (1988-1997)

In this period, the largest forest fire which was ignited on Goseong in Kangwon province was occurred in April 1996. This fire had many impact on various area related to disaster in Korea. Therefore, the government was newly organized 'The controller of forest fire' in Korea forest service which supervised the task related to forest protection and prevention and attack of forest fire in 1996. The department of forest fire prevention training was newly organized in forest human resources department institute. The air unit and ground attack unit were organized and large-sized helicopter like KA-32T was introduced. Various equipments for surveillance and ground attack was introduced and skills were improved.


<The opening ceremony for the organization of forest fire ground units on Seoul in 1996>

6. The period of the forth basic plan of forest (1998-2007)

In this period, the largest forest fire to today named ‘eastern coastal forest fire’ was occurred in 2000 and Yang Yang forest fire, which destroy Temple of Naksan was occurred in 2005. For these large damages of forest fire, the forest fire was regulated as national disaster. for surveillance and ground attack was introduced and skills were improved. The national interest like this made Korea forest service to build a forest fire action plan quickly

The prescribe for task and role of forest fire institution was legislated as Korea forest service regulation 588. This determined the task and role of institution when forest fire occurred clearly. The combined guideline of field command for forest fire attack and field manual were enacted following large forest fire case. The forest fire management center for eastern coastal region opened in this period.

<The eastern coastal forest fire on Samcheok in 2000>

<The YangYang Forest fire in 2005>

<The joint training of forest fire ground units in 2004>

<The air attack by large sized helicopter(S-64E) in 2002>

<The forest fire damage on the temple of Naksan in 2005>

7. The period of the fifth basic plan of forest (2008-present)

In this period, The main theme of plan was ‘scientific forest fire disaster prevention and action’ as tactical task of forest protection which was an important resource. The detail of this plan was composed three parts. First was the establishment of scientific surveillance system and backfire countermeasure. This meant the development of prior action system. Second was the specialization of forest fire management organization. And third was the development of advanced technique for forest fire prevention and attack action. The last was development of skill for rapid restoration and re-forestation.

Especially, the totally government measure was reinforced. The special forest fire measure of great drought in 2009 and the legislation of ‘the law of forest conservancy (2010)’ which integrated various regulations related forest fire divided various laws, and time-, reason-specific measure was a good example in this period. The improvement of fore fire surveillance technique and attack skill was implemented. The conditions control systems and forest fire mechanized system and equipment using IT technique was a example of advancement in this period.

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WRF-fire Simulation of the 2005 Yangyang, Gangwon Province Forest Fire

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Abstract

In dry spring season, mountainous Gangwon province is one of the most vulnerable area to forest fire in Korea. Yangyang Forest Fire in 2005 was a disaster due not only to its huge burnt area but also to the loss of historic temple building, Naksan temple.

This study tried to simulate the Yangyang Forest Fire using the WRF-fire modeling system. Even though there are no such high resolution topographic and fuel data available as is needed to simulate the fire adequately, the simulated fire-line was fairly similar to the actual fire spread. From the simulation result it was found that the WRF-fire system could be a useful tool to predict fire-lines for extinguishing activities in the near future when such high resolution topographic and fuel data as few meters become available in Korea.

Introduction

As the fire-spread model became coupled in the WRF meteorological modeling system in recent years, the meteorological research communities such as NIMR/KMA got interested in the fire-spread prediction. The so-called WRF-fire modeling system works in such manners that the atmospheric part provides wind fields with the fire modeling part while the fire modeling feeds the heat and moisture flux back to atmosphere in the lowest model layer.

The coupled fire model computes the fuel burning in the subgrids within atmospheric land-surface grids as a function of wind, fuel, and topographic height. The subgrids are in general less than 1/10 of atmospheric grids. Thus, fire modeling works in far finer grids thant those of atmosphere requesting very high resolution fuel and topo data. In general, those of 1/3 arc seconds are required for reasonable simulations of fire-spread from the WRF-fire modeling system.

In dry spring season, mountainous Gangwon province is one of the most vulnerable area to forest fire in Korea. Yangyang Forest Fire in 2005 was a disaster due not only to its huge burnt area but also to the loss of historic temple building, Naksan temple.

In order to simulate the Yangyang Forest Fire, the authors made use of the land cover data obtained from Korean Ministry of Environment in geographic information system format in order to generate 4-meter resolution fuel data. Thus, it was made possible to run the WRF-fire with reasonable results.

Methodology

The WRF-fire modeling system was used to simulate the Yangyang Forest Fire of Gangwon province in 2005.

The atmospheric initial and boundary conditions for the fire simulation were provided by 5-km resolution short-range modeling system in KMA which is called KLAPS.

The grid spacing for the fire model subgrids is 50 meters which is 1/20 of 1-km atmospheric grid.

The 4-meter resolution fuel data set of Anderson 13 categories were prepared using land cover data set from Korea Ministry of Environment.

Results and Discussion

In Figure 1, the example image of simulated fire-burning area of the Yangyang Forest Fire is suggested in 3-dimensional view image. Compared to the actual burning area the simulation seems to be quite useful, because we expect the result will be much better when the fuel data is more realistic in terms of resolution and fuel category.

Thus, further efforts to obtain the realistic fuel data are required to have more realistic fire-spread forecasts.

Figure 1. The 3-dimensional image of the simulated Yangyang Forest Fire.

Soap-based Firefighting Foam for Forest Fire, Current Forest Fire Situation in Japan

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Abstract

Class A firefighting foam concentrates, containing surfactants in major proportions, reduce the usage of water for firefighting. Due to the characteristic properties of surfactants, the agents reduce surface tension of water, and create a superior foam blanket when mixed with air. Thus, it allows firefighters to extinguish a fire much faster than water alone. In Japan, however, the firefighters hesitate to use these agents because they show significant toxicity against aquatic organisms. In other countries, some worry about the environmental impact from firefighting activities using the firefighting foam. We have been developing a novel firefighting foam concentrate with significantly lower environmental risk, consisting of soaps, chelating agent, and diluents. Soaps are the key major components in our firefighting agent, and possess very high biodegradability and very low toxicity particularly for aquatic organisms such as a fish.

In this presentation, I will talk about the novel firefighting foam for forest fire and current forest fire situation in Japan.

INTRODUCTION

We have worked on "Environmentally Friendly Soap-based Firefighting Foam" with the Kitakyushu City Fire and Disaster Management Bureau, Shabondama Soap Co.,Ltd, and the firefighting enterprises since 2003(Mizuki et al., 2007; Goto et al., 2007;Mizuki et al., 2010). The novel firefighting foam for structure fire was a commercial reality in 2007. This activity is consistent with policy of Kiakyushu city that has a magnificent heritage of techniques and human resources as a "manufacturing city" and aims to become the "World Capital of Sustainable Development". The collaboration among industry, academia, and government is useful and powerful, and the teamwork is will be further advanced through the mediation of the new research center.

The Research and Development center of Fire and Environmental Safety (RDFES) was established in April 2008 as a research institute within the Faculty of Environmental Engineering, the University of Kitakyushu. The RDFES is the first academic institute in Japan to contribute to environmental engineering and firefighting technology for social safety, and focuses on the environmental researches to overcome the worldwide serious firefighting problem, for example huge forest fires, and consequently contributes to create the epoch-making products for the environmental conservation and the safety of citizens.

In this project, we have been developing a novel firefighting foam concentrate with significantly lower environmental risk, consisting of soaps, chelating agent, and diluents. Soaps are the key major components in our firefighting agent, and possess very high biodegradability and very low toxicity particularly for aquatic organisms such as a fish. Furthermore, the ecotoxicological evaluation and the environmental risk assessment will be performed. This project has been promoted by the collaboration among Shabondama Soap Co.,Ltd, Morita Holdings Corporation, the University of Kitakyushu, and Kitakyushu City Fire and Disaster Management Bureau under Japan Science and Technology Agency (JST) Project, Adaptable and Seamless Technology Transfer Program through Target-driven R&D (2009-2012). The research in this program is based on fundamental findings from universities, etc., and aimed at developing toward commercialization via regional industry-academia-government collaborative research.

EXPERIMENTAL

Constituents of Soap-based firefighting Foam Concentrate

The long chain fatty acid salts, oleate andlaurate, were themajor components. The highly biodegradable chelating agent,methylglycinediacetic acid (MGDA) saltor N,N-Bis (carboxymethyl) glutamate tetrasodium (GLDA) saltwas added to the soap-based firefighting foam concentarate. Propylene glycol (PG) andhexylene glycol (HG) were also added to maintain fluidity.

Foaming Test

4L of fire-fighting agent solution at 293K were sealed into the fire pump (capacity 8 L). Next, nitrogen gas was poured in the fire pump up to 0.85 MPa. The solution was drained off from the firepump to a bubble collection tank (made of stainless steel, 200 mm × h 1200 mm). The steady-state foam height was measured as the distance between the bottom of the tank andthe top of the foam, andthe bubble rate was calculated.

Pour Point Test

This test was based on Japanese Industrial StandardsK 2269 (the pour point test method). Ice, sodium chloride, and dry ice were used to lower the cooling bath temperature. 45 mL ofthe sample (firefighting foam concentrate) was poured up to the test tube’s marker height and was sealed. The test tubewas installed in the outer tube and warmed up to 315 K. The sample was retained for 5 s at the preset temperature. The pour point is defined as the temperature at which the sample lost the fluidity.

Toxicity Assay

For toxicity assays, paramecia in the stationary phase were washed once with the EBIOS medium made up with the ultra-pure water and then washed twice with the EBIOS media made up with different waters to be used. The tests with *P. bursaria* were carried out on 12-well microplates. Each well on theplates was filled with 0.9 mL of EBIOS media harboring100 paramecium cells plus 0.1 mL of detergent solutions.Then the cells were incubated for 12 h at 296 K under continuous dark condition, and the numberof living cells was counted at the end of incubation nunder a stereomicroscope (SMZ645; Nikon, Tokyo). Medaka fish was also used for toxicity assays of soap-based firefighting test according to the previous paper (Lin et al., 2006).

Biodegradability Test

Activated sludge from a wastewater treatment plant was used as the medium exposed to soap-based firefighting foam concentrate. Batchrespirometric tests are commonly used to identify organic fractions and kinetic parameters in aerobic biological processes (Yasui et al., 2008). Since oxygen consumption isassociated with biological substrate removal from the liquor and bacterial growth/decay in the system, the respirograms allow construction of a reliable modelstructure. Oxygen uptake rate were obtained using a batch respirometer (Challenging SystemsInc., USA (AER-8)). The temperature of the incubation vessel and the sensing device were maintained at 297 K in a temperature-controlled incubator. For collecting oxygen uptake rete, a small scrubber consisting of caustic material was set between the incubation vessel and the sensing device to absorb CO_2 produced by bacterial respiration from the headspace gas.

RESULTS AND DISCUSSION

When water is discharged to burning materials, most water flows out and contributes little inextinguishing a fire because of its high surface tension.

Firefighting foam concentrate containing surfactants reduces the water surface tension and induces foam formation. The water can stay around theburning materials for a long time and fulfill its role as an extinguisher. Therefore, the wettability, foaming property, and foam stability are required for firefighting foam. From the results of preliminary experiments, the foaming property is found to correlate strongly with the firefighting performance. The fluidity of firefighting foam is also important so that it is available even in coldseason. The bubble rate and the pour point are useful indicators for the foaming property and thefluidity.

Sodium oleate, potassium laurate, and potassium palmitate were employed as soap components since they are well known to enhance the wettability, the foaming property, and the foam stability of aqueous solution. Soap combines easily with minerals such as calcium and magnesium ions in tap water. It is also able to lose the interfacial activity immediately. Chelating agents should be added in a soap-based firefighting foam to inhibit the soap-mineral complex formation in tap water. MGDA and GLDA possessing an amino acid backbone were selected as a chelating agent because of its better biodegradation behavior. Diluents containing PG and pure water were added to maintain the fluidity of the agent. From the results of the foaming test and the pour point test, the percentage of fatty acid salt, chelating agent, and diluents are determined to be 14.0 wt. %,33.4 wt. %, and 52.6 wt. %, respectively.

The acute toxicity of oleate, laurate, and palmitatewas evaluated using green paramecia (*Paramecium bursaria*) and *Paramecium caudatum* under various water conditions. In the low mineral culture medium prepared with distilled water, the median lethal concentration (LC_{50}) for each fatty acid ranged from 5.8 to 144 ppm (w/v). The toxic levels of fatty acid salts differed in the following order: laurate $\geq$ oleate, palmitate. The toxic levels of oleate and palmitate salts were ca. 10-fold lower than those of laurate salt. When river water and local tap water were used for culturing instead of ultra-pure water, the toxic levels of all fatty acid salts were drastically lowered compared to the low mineral condition by 30- to 100-fold (198-660 ppm w/v). Similar detoxification effects were observed when Ca or Mg was added to the low mineral culture media, indicating that the toxicity of fatty acid salts can be notably lowered as the mineral content increases. The toxicity of GLDA is equal to the toxic levels of oleate and palmitate salts. Surprisingly, the toxicity was decreased when GLDA and laurate salt coexist. Other constituents have also low toxicity to green paramecia.

Three biodegradable fractions in the soap-based firefighting foam were observed from the aerobic respirometrictests. The three fractions are considered to be fatty acid salts, the chelating agent GLDA, and the glycols (PG and HG). All fractions were found to degrade within the first day of incubation. Kinetic modeling of the degradation of the soap-based firefighting foam was studied by aerobic respirometric analysis. The model for aerobic degradation of the soap-based firefighting foam was based on ASM1 (Yasui et al., 2008). The three fractions showed different degradation kinetics, and the biological degradation rate is almost comparable as the typical organic matters in sewage.

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Spatial pattern of human caused forest fire in Korea

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Abstract

Most forest fires in Korea are concentrated in certain areas spatially and they are also highly related to human activities. This site-specific characteristic of forest fire can be analyzed by spatial analysis, such as generalized linear mixed model (GLMM) with spatial structure which considers spatial autocorrelation. In this article, we used GLMM approach to quantitative effect of topology, human accessibility and forest cover with spatial autocorrelation. Under assumption these factors, which are slope, elevation, aspect, population density, distance from road, forest cover, are related to forest fire occurrence, the explanatory variables of each factors are prepared using GIS based process. The explanatory variables are transformed for linearity.

We firstly tried to test the fixed effect of forest fires and to explain which factors influence in occurrences of forest fire by using generalized linear model (GLM) with Poisson distribution in the meanwhile over-dispersion of response data also detected and variogram analysis was performed by using standardized residuals of GLM. Secondly, GLMM was applied to optimize the fixed effect and random effect. Fitted results were validated with correlation test and RMSE. The result of this study shows that the slope, elevation, squared aspect index, population density and distance from road were determined as significant factors which can explain forest fire occurrence. The spatial parameters were estimated to 32.04 kilometers as range and 0.485 as nugget. The results of GLMM were more stable without outlier than those of GLM. Finally forest fire risk was mapped. The risk near the region with high population density was relatively high. Elevation shows the suppress effect on fire.

Keywords: forest fire, wildfire, mixed model, spatial autocorrelation, variogram.

INTRODUCTION

Forest fire is one of the major disasters which damage both forest ecosystem and human society. And it is very strong threat in Korea because about 65 percent of Korean peninsula is covered by forest. If we take a look into the reason why forest fires are occurred, all the forest fires in Korea are caused by human. There is no natural fire by lightening on condition of Korean meteorology. Because most forest fires are closely related tohuman activities, the fires have a tendency to be occurred on spatially concentrated sitesrepeatedly in Korea. The most frequent reason is accidental fire by human. The second is fires by field incineration (Kwak et al. 2009). To prevent forest fire caused by human activities, it is important to know which factors are related and how much the influences is to the forest fire occurrence.

Spatial count data arise in many situations in epidemiology, ecology, and agriculture (Zhang 2002). Typical methods of statistics have limits to detecting specific relationship including spatial autocorrelations. So it is needed more additional techniques and handling count data with spatial autocorrelation is being important for ecology and forestry. To analyze spatial autocorrelation, geostatistical methods are well known for point based data and recently hybrid method so called regression-kriging was adopted which is kinds of mixed model with general regression and ordinary kriging (Hengl et al. 2007; Hengl et al. 2004; Oliver 1990; Stein 1999). In statistics, the effort to consider spatial effect in regression model is also proceeding. The researches for stabilization of mixed model, many GLMM models based on different assumption were prepared (Christensen 2002; Diggle 1998; Venables and Ripley 2002; Zhang 2002). These methods are used in variety field of researches not only forest fire but also epidemiology, social geography, remote sensing and so on. Spatial distribution is very important in forest fire, specially a hundred percent of fires are occurred by human, many spatial analyses have been adopted.

STUDY SITE

The study site is entirety of South Korea (Figure 1).

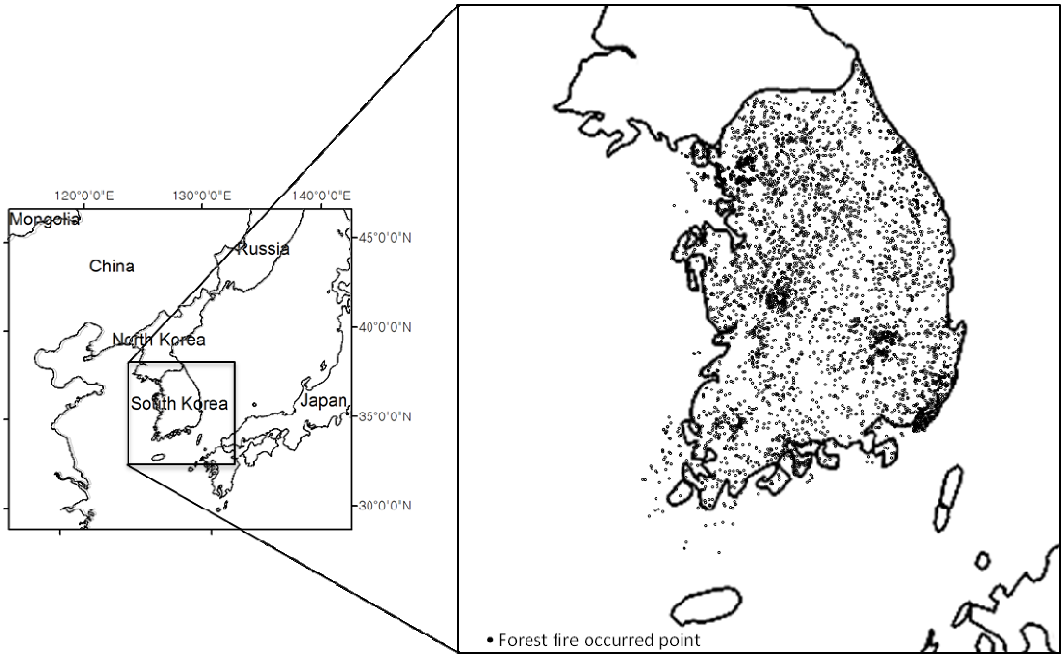


Figure 1. Study area with the points of forest fire occurrence

MATERIALS

Forest Fire Data

In Korea, almost 74.2 percent of forest fires are occurred in spring season (Figure 2). Because there are public holiday and traditional celebrate day which are usually done ‘in or near’ the forest area in this season, people who have activities in the mountain and forest area are dramatically increased. From this we supposed that human accessibility was highly related to forest fires in Korea. Forest fire occurrence history was collected by Korea Forest Service (KFA). This daily fire point contains information of occurred time and address. The address of fire occurrence was geo-coded to let data have spatial coordinate by using a land registry map from Korea Cadastral Survey Corporation.

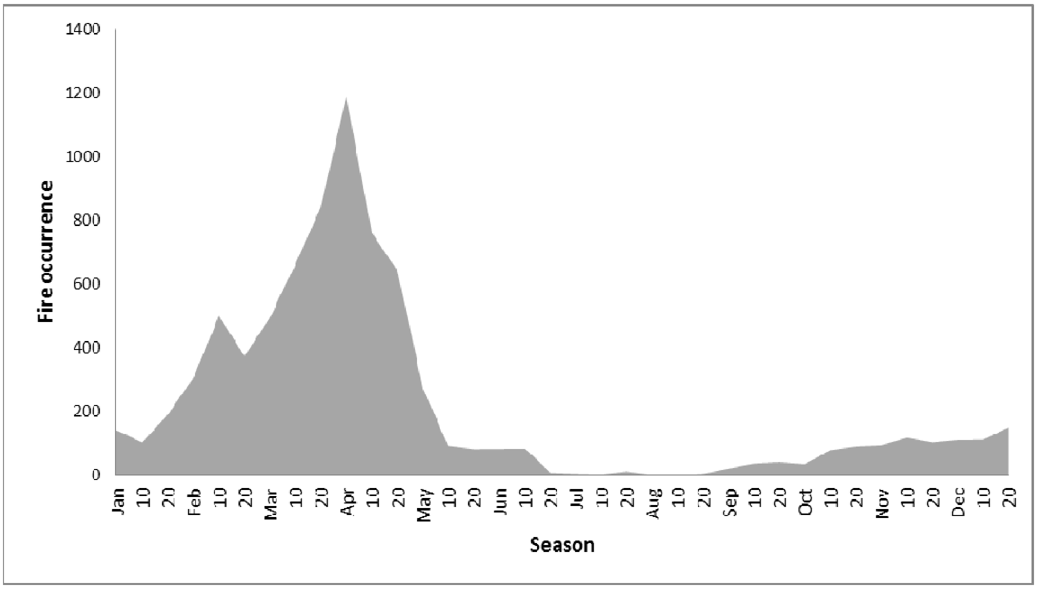


Figure 2. Seasonal variation of forest fires count which is summed from 1991 to 2008.

The point data was converted to density data with 5km quadrats for quantitativeness (Figure 3). The reason we fixed the size of quadrat to 5km is to minimize an error on converting point to quadrat count because the average of polygon area of land registry map which was used for geo-coding was within 25 square kilometer. After that, mean value of all external variables which consist of topographical factors, human accessibility and tree species factors within quadrats also were input. Totally 4474 grids cover whole study site, South Korea. For model estimation, half of grids which are 2237 were used. The others were used for mapping of results and validation.

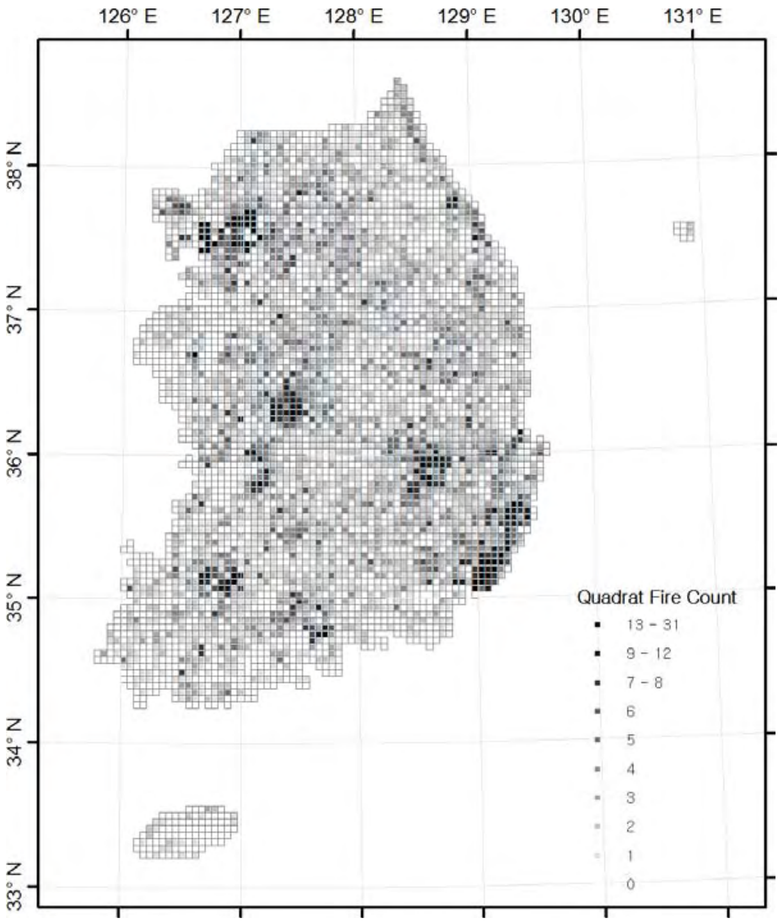


Figure 3. The distribution of forest fire by 5 km quadrat count.

Explanatory Variables

In this study, we focus on the spatial characteristics of forest fire occurrence, not temporal characteristics. So we supposed that the important factors which influence forest fire occurrence are three major reasons related to spatial distribution. That is topographical factors, tree species and human accessibility which arestatic spatial factors.

Spatial Autocorrelation

Spatial data have a property of spatial autocorrelation which is hard to be explained by ordinary statistical method because observations are more related to nearby locations than would be expected (Anselin 1988; Legendre 1993). The first law of geography which related to this phenomena is known as follows: “Everything is related to everything else, but near things are more related than distant things" (Tobler 1979). So, when it comes to spatial characteristics, a spatial-considered tool should be employed to analyze the spatial dependency.

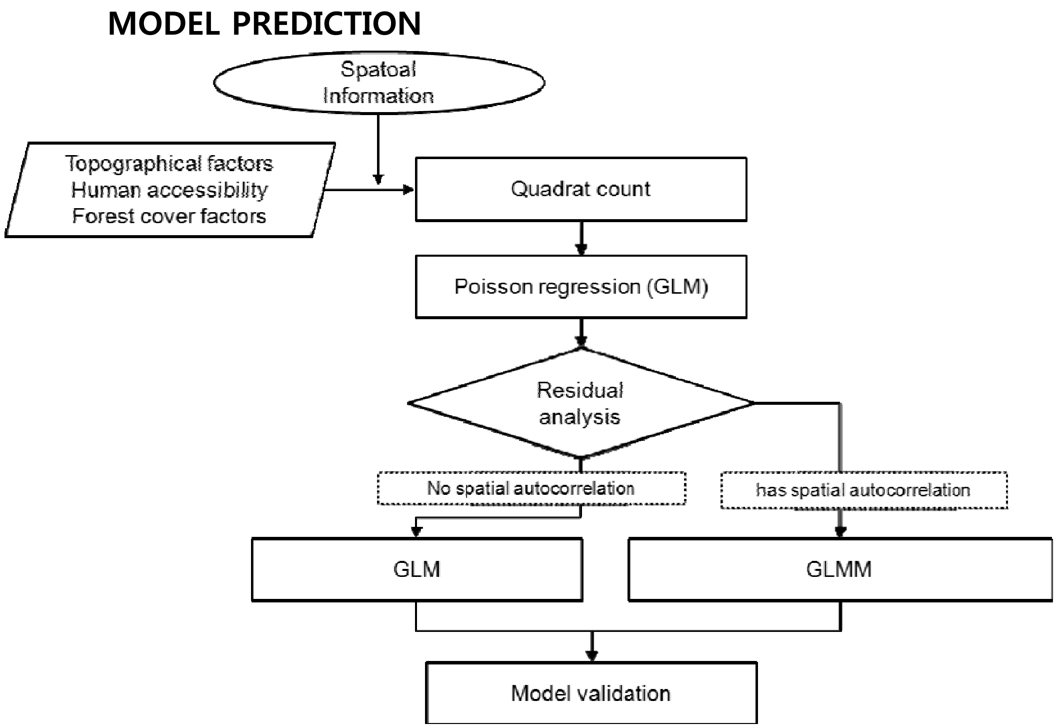


Figure 4. Process for predicting forest fire occurrence with GIS based quadrat count data and GLMM in this study.

RESULTS AND DISCUSSION

Model Estimation

Coefficients of GLM and GLMM were estimated with general linear model shown as Table 1. The population density was the best explanatory variable which has lowest standard error and p-value. It shows that population density factor can explain the linear relationship to forest fire. The distance from road was also highly significant. These results show that human accessibility is considerable factors in forest fire. Topographic factors also showed high relationship except the aspect index in GLMM. In GLMM the significance was decreased on aspect index. Distance from the road and elevation have negative effect on forest fire occurrence. If the values of these factors are increase, people have limit accessibility. Quite large differences of coefficients between GLM and GLMM were existed in intercept and aspect index factors. The ranking of forest cover class in terms of fire occurrence probability was Etc> Grassland > Needle leaf forest > Mixed forest> Broad leaf forest. Etc class of forest cover means forest which is not used for tree growth and this class is distributed near city and army community. Grassland includes cultivated land, pasture and fruit garden. In winter, field incineration which have done illegally make large number of fires in Korea.

Table 1. Estimated Coefficients, standard error and significant level

Variables	GLM			GLMM		
	Coefficient	Std. error	P-value	Coefficient	Std. error	P-value
(Intercept)	0.6482	1.047	0.53594	1.8048	1.3684333	0.1873
Population density(KDE)	1.865	0.6629	< 2e-16	1.74	0.12	< 2e-16
exp(Distance from the road)	-2.237	1.011	0.026974	-3.462	1.335	0.0095
Elevation	-2.765	0.2087	< 2e-16	-2.236	0.3175	< 2e-16
Slope	0.02498	0.0048	2.12E-07	0.0239	0.00522	< 2e-16
Aspect Index	0.6805	0.2696	0.011668	0.3317	0.262588	0.2067
Aspect Index^2	-0.5829	0.1503	0.000108	-0.3760	0.1487	0.0115
Needle leaf forest	0 (N/A)	-	-	0 (N/A)	-	-
Broad leaf forest	-0.1771	0.06368	0.005452	-0.196015	0.0868437	0.0241
Mixed forest	-0.08805	0.08667	0.309766	-0.20387	0.1024206	0.0467
Grassland	0.2057	0.2276	0.366146	-0.111335	0.3062483	0.7162
Etc	0.4161	0.1907	0.029184	0.215232	0.233607	0.357

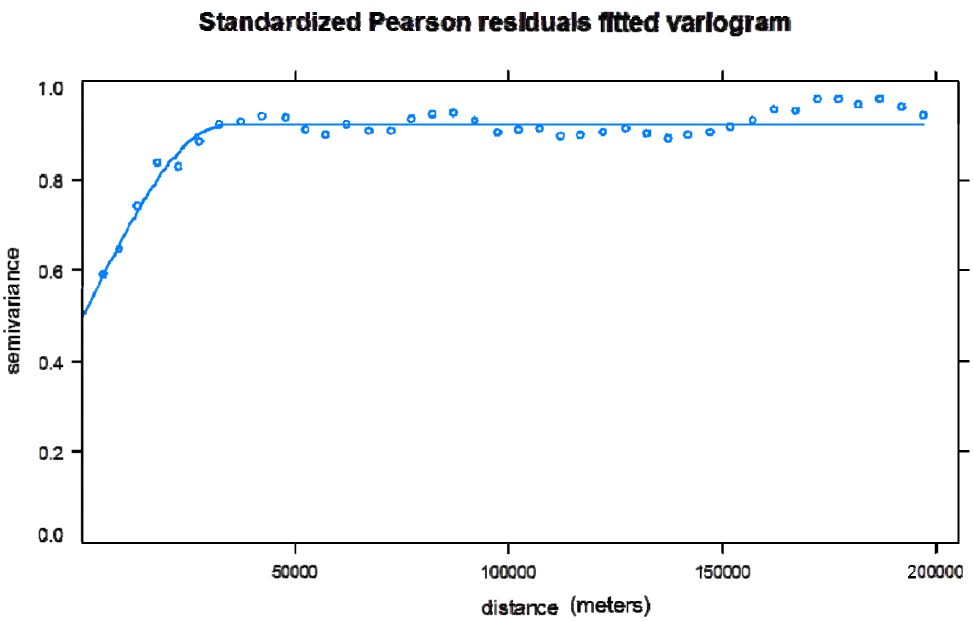


Figure 5. Variogram of standardized Pearson residuals of GLM.

Variogram of standardized Pearson residuals are shown as Figure 5. They were fitted with the spherical models which have the coefficient value as Table 2. In variogram analysis the sill is the value at which the variogram became flat. It means the variance of the two separated point of spatial data. The nugget relates to the variance between pairs of points separated by very small distances (Western et al. 1998).

Table 2. Estimated coefficients of the random effects (Spherical spatial structure).

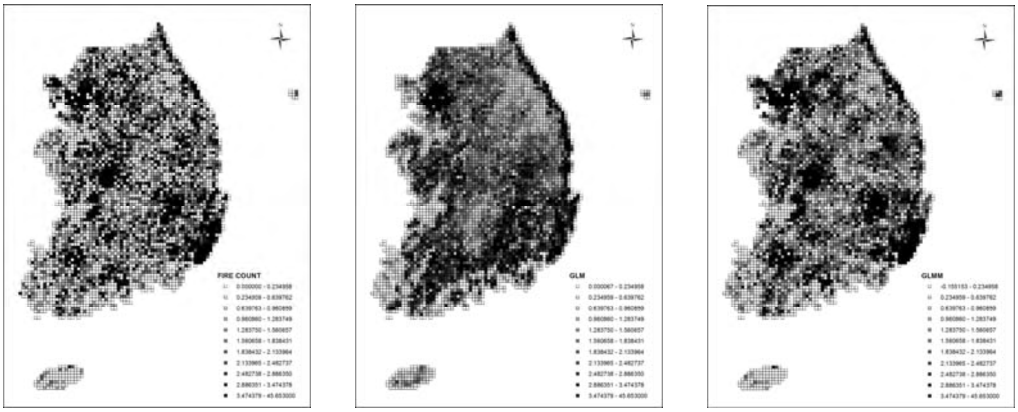
Model	Primitive estimation by Standardized residuals of GLM		Estimated GLMM spatial structure	
	Parameter	Value	Parameter	Value
Spherical	Range	33298.55	Range	32039.60
	Sill	0.9210	Sill	-
	Nugget	0.4966	Nugget	0.4851

Probability Maps

Prediction map of forest fire occurrence was derived from estimated risk. The spatial characteristics of forest fire occurrence which are expressed in the prediction map show that strong relationship between forest fire and the population factor. The megacities such as Seoul, Daejeon, Daegu and Busan have high forest fire risk. And the forest area also well reflected on analysis. The western part of peninsula which has low forest area shows relatively low fire danger. And the high elevation area through Taebaek Mountains and Sobaek Mountatins which is located on Eastern part has low level of fire risk. It seems to reflect the topographical factors well so it shows the high similarity to the real fire distribution.

And in terms of the distribution of fires risk, the map from GLM shows that a high risk region is scattered irregularly (Figure 6). On the other hand, estimated risk by GLMM shows more clustered pattern which is similar with real distribution of forest fire occurrence (Figure 1). The tendency to be concentrated to hot spot was increased on GLMM. It means GLMM reflects the spatial correlation well.

In risk prediction, we summed up kriged residuals to estimated risk by fixed part of regression (Kleinschmidt et al. 2001). For this step, kriged standardized residuals were converted to raw residuals for mapping. When risk map was predicted, GLMM can consider ordinary kriging for interpolation and it can consider different spatial structure, such as spherical, Gaussian, exponential. But it is known that extrapolation is more difficult problem in spatial data and temporal data (Dormann 2007). The further objective of fire risk model should be focused on spato-temporal prediction. However, if meteorological factors are added in mixed model for temporal variation, prediction will be more difficult problem than spatial aspect.



(a) Observed fire count (b) GLM (c) GLMM

Figure 6. Prediction map of GLM and GLMM

CONCLUSION

The aim of this study is to predict forest fire occurrence using spatial data. Furthermore to improve the accuracy of the GLMM model was applied for the enough reflection of spatial dependency. In this model geostatistical spatial structure was added to the ordinary regression. Because a quadrat count of forest fire is known that it follows the Poisson distribution, a Poisson regression was employed to estimate the external influences of parameters. But over dispersion was detected on data, it was adjusted by scale factor.

In the result of GLM, the population density was highly significant factor on fire occurrence. Elevation and slope were also significant. There was spatial autocorrelation in the standardized Pearson residuals when variogram analysis was performed. Spatial parameters were initial value for spatial structure in GLMM. GLMM showed more stable and clustered result than GLM and the predictions are more related each other spatially.

Spatial autocorrelation is important factor for estimation in statistical model. Also, spatial autocorrelation can be useful factor in management of forest fire. Since most fires are caused by human, spatial autocorrelation may be understood as determination factor which is related to distance. For example, decision making of fire guard network can be done. High density network should be in range of around 30kilometers from high risk region according to spatial autocorrelation.

Especially, we focused on spatial characteristics so the temporal consideration was insufficient such as climate factors. But considering spatial part is cornerstone of spatio-temporal analysis. In the next research, the climate condition which has temporal information should be incorporated to analyze the seasonality of forest fire.

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INDONESIAN FOREST FIRES MORATORIUM AND GREENHOUSE GAS EMISSION REDUCTION

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Abstract

Indonesian goverment promised to reduce GHG emission by 2020 as much as 26 % or 41 % if supported by International cummunity. It could be realized if the main contributor of GHG emission seriously managed and solved. Forest and land fires is one of the main contributor for Indonesian greenhouse gas emission which produce during burning through land preparation using fire done by the local people or commercial activities, which lead to the global climate change impact direct or indirectly. Avoiding the forest and land fire will be one of the best solution. It could be reach not only by fighting the fires but also through goverment regulation and sustainable forest management such as moratorium.

Keywords: moratorium, fire, emission, reduction, GHG

INTRODUCTION

Forest fires occur either because of anthropogenic or natural causes. The majority of fires around the globe are caused by human activity. It has been estimated that annually fires been across up to 500 million ha of woodland, open forests, tropical and sub-tropical savannas, 10-15 million ha of boreal and temperate forests and 20-40 million ha of tropical forests (Goldammer, 1998). Fire is one of the oldest tools known to humans. It has been used as a management technique in land clearance for centuries. For the thousands of farmers, ranches and plantation owners on the edge of the agriculture frontier pushing into forest, fire is the obvious mechanism. It is normally the least expensive and most effective way of clearing vegetation and of fertilizing nutrient poor soils (Rowell and Moore, 2000). Human probably had a role in starting forest fires in recent millennia, and may have deliberately burned forest to improve hunting for thousands of years (Qadri, 2001). As prehistoric human settlers of the Indonesian archipelago began to switch from hunting and gathering to growing crops, they use fire to clear agricultural plots in the forest. The cycle of forest clearing, cultivation and abandonment is known as Swidden, kaingin or shifting cultivation, an agricultural system adopted throughout most of the region over a period of thousands of years.

INDONESIAN FOREST FIRE SITUATION

With the stepping up of economic activities in Indonesia's outer islands, forest fires have become common place, occurring every year. During pronounced *El Nino* years, when conditions are usually dry, fire and smoke problems tend to be much more serious. Serious fire occurred in 1982-1983, 1987, 1991-1992, 199401995, and 1997-1998. Less serious fires occurred in 1999. Again significant fires have been reported in March 2000, 2002, 2004, 2006.

Based on data made by Department of Forestry (2007), it had been known that until 2006 the increasing of hotspot was very significant as it can be seen that from 8 (eight) fire risk provinces in Indonesia only North Sumatra which produce less hotspot (-6.50%), meanwhile other provinces produce more hotspot that varies from 56.54 % until 1,738.75 %. The total forest and land burned during 2006 predicted about 6 million ha. Number of hotspot during 2006-2007 according to the data taken by Department of Forestry (MoE, 2008) shown that hotspot detected decreased significantly compared to hotspot detected in 2007 at average of 71.39 %. Most of hotspot detected in the period of January-December 2007 totally about 10,280 or about 64.07 % was in the community (MoE, 2008), followed by hotspot detected in the estate crops was 2,644 (16.48%) in the estate crop, in the forest concession was 1,691 (10.54 %) and in the forest plantation was 1,430 (8.91 %). Hotspot detected in peat land during January-December 2007 totally about 3,127 both in Sumatra (2,036) and Kalimantan (912) or about 20.05 % compared to the all hotspot detected, 16,045 (MoE, 2008). Hotspot detected in mineral soil totally about 12,828 both in Sumatra (5,866) and Kalimantan (6,962) or about 79.95 % compared to the all hotspot detected.

Based on hotspot data made by Minstry of Forestry, it had been knwon that the total hotspot detected during the year 2008 was 30,704 and in the year 2009 was 37,659 hotspots (until 16 November 2009) that was separated in the forest area about 22.6 % (8,493 hotspot) and non forest area 77.4 % (29,081 hotspot) means hotspot in the year 2009 increased than in the year 2008. Hotspot detected in the year 2010 was also significantly decrease compared to the previous year

2009, 2008 and 2007.

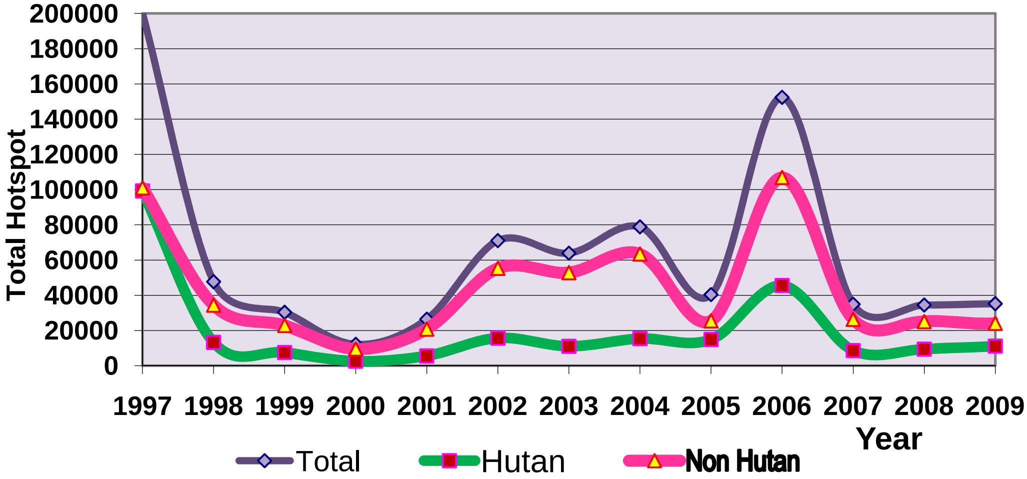

Figure 1. The hotspot detected during 1999-2009 (Bappenas, 2009)

INDONESIAN GREENHOUSE GAS EMISSION

An assessment of Indonesia's peat land GHG emissions from fire, peat oxidation and loss of AGB, completed according to IPCC Tier 2 standards, shows average annual net emissions of 903 Mt CO_2 yr^{-1} between 2000 and 2006 (Bappenas, 2009). This estimate is based on (a) team estimates of emissions from oxidation of 220 Mt CO_2/yr using land use and land cover data from 2000-2006 and previously published emissions factors, (b) loss of AGB of 210 Mt CO_2/yr based on past rates of deforestation and carbon stock in peat swamp forests and (c) a fire emissions estimate of 470 Mt CO_2/yr from van der Werf *et al.* (2008) that has been disaggregated into controlled and uncontrolled burning. Controlled burning is defined as fires occurring in land converted into peat and agricultural land. This estimate is broadly similar to the National Climate Change Council estimate and the data presented in the Second National Communication (SNC) to the UNFCCC. Following on from the peat CO_2 study, van der Werf *et al.* (2008) used several approaches to estimate annual average fire emissions from peat and forest fires. Their mean annual estimate from 2000-2006 of 470 Mt CO_2/yr is now widely accepted, and this study has been used for both the Indonesian National Climate Change Council (DNPI) assessment of the national GHG cost abatement curve and the Government of Indonesia's Second National communication

(SNC) to the UNFCCC.

EMISSION REDUCTION

The majority of the peat emissions during 2000-2006 period were estimated to be a result of uncontrolled burning (defined as fires occurring outside of licensed areas and contributing 46% of total emissions), peat oxidation (25%) and biomass removal (24%) with the main source regions being Sumatra (44%) and Kalimantan (40%) (Bappenas, 2009). Emissions show a strong inter-annual variation due to factors that influence dry season rainfall such as El Nino and there has also been a reduction in loss of peat swamp forest in the period 2003-2006. Sumatra and Kalimantan dominate the national peat emissions profile with fire-related emissions being greater in Kalimantan than Sumatra, while oxidation emissions are greater in Sumatra than Kalimantan. This pattern probably reflects the fact that development peat land in Sumatra preceded that in Kalimantan.

These facts shown that fire emission which estimate around 470 Mt CO_2/yr is the significant greenhouse gas emission that should be gradually reduced. There are several activities could be done regarding the reducing of greenhouse gas emission in term of forest fire such as forest fire prevention and suppression activities. Protection of forests from fires accroding to Indonesian goverment (Bappenas, 2009) would be taken through the following activities: enhancing coordination among stakeholders and roles of local institution, improving the infrastructure and equipment of fire control, strengthening the fire brigade “Manggala Agni”, avoiding and extinguishing forest fires in areas that are prone to fires, handling post forest fires and developing early warning system through hotspots monitoring with NOAA and MODIS. In order to make sure every activity well done, several target indicator established such as reduction of hotspots in Kalimantan, Sumatera and Sulawesi -20% per year, area of forest burned reduced 50% compared to the condition of year 2008 and increase the capacity of local government and community in controlling forest fire hazard in 30 operational Areas (Bappenas, 2009). Others activities would be done also to reduce fire emissions in term of fire prevention activities such as law enforcement, land preparation without fire, demonstration plot and incentive to the local people who do not use the fire for land preparation.

Reducing deforestation alone has according to some scientist, the potential to conserve 1.5 Gt of carbon per year. It will also preserve species which we may need under elevated CO2 regime. Proper management in forestry and agriculture is a prerequisite for a stable global climate. It is much cheaper in the long run and makes more sense to manage and conserve present land resources-which includes other value added benefits-than to continue with present unsustainable practices (Sorensen, 1993). Research done in the burnt peat swamp forest in Central Kalimantan, Indonesia, shown that moratorium fire and logging will give better environment to vegetation to grow up which increased above ground carbon stock due to the increasing of above ground biomass. Repeated burned site above ground carbon stock only 6.49 ton/ha, while 15-years undisturbed secondary peat swamp forest burned carbon stock 132 ton/ha. According to the Bappenas (2009) emission reduction target (Table 1), the main activities related to forestry and peatland is avoiding forest fire and combating illegal logging.

Table 1. Indonesian Emission Reduction Target (Bappenas, 2009)

Sector	Emission Reduction Plan (Giga ton CO2e)		Action Plan	Agency
	26 %	41%		
Forestry and Peatland	0.672	1.039	Controlling forest fire and peat fire, Water resource management, Forest and land rehabilitation, HTI, HR. Reducing Illegal Logging, Avoiding deforestation, community engagement.	Ministry of Forestry, Ministry of Environment, Ministry of Public Work, Ministry of Agriculture
Waste	0.048	0.078	Building Landfill, wasting management based on 3R and integrated water waste management in urban area	Ministry of Public Work, Ministry of Environment
Agriculture	0.008	0.011	Introduction low emission rice, water irrigation efficiency, applying organic fertilizer	Ministry of Agriculture, Ministry of Environment
Industry	0.001	0.005	Energy efficiency, applying renewable energy	Ministry of Industry
Energy and transportation	0.038	0.056	Applying bio fuel, engine efficiency	Ministry of Transportation, Ministry of Energy, Ministry of Public Work

CONCLUSION

Avoiding forest and land fire as the main contributor of GHG emission in Indonesia will be one of the best solution to reach the emission reduction target. The activities done to reach the target actually not only fighting the fire during the fire season but it could be reach also using the legal formal approach such as moratorium that initiated by the government. It will be better if the field implementation realized through sustainable forest management manner such as do not let repeated burning occur and keep burnt forest area un-touch for certain period of time.

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KEYNOTE SPEECH II

Climate Change Impacts on Forest Fire Characteristics and Restoration Strategy in Korea

기후변화에 따른 한국의 산불전망과 피해지 복원 전략

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Abstract

Global change resulted from climate, population, and land use change, is altering the fire regimes. The decadal variability of the occurrence of forest fire for the recent two decades from 1991 to 2008 was analyzed. Across the Peninsula, forest fire frequency is negatively correlated with monthly mean temperature, relative humidity, and precipitation amount, while positively correlated with the monthly days without precipitation and the average duration of no precipitation for the total data period. To adapt to global change, Advanced and integrated forest fire strategies such as targeted social program based on accurate fire causes, communities-based fire management, fuel management and international cooperation program were needed. Forest ecosystem suitability and economic benefit of local residents should be considered in restoration of burnt area by forest fire.

요 약

기후변화, 인구변화, 토지이용변화 등으로 초래된 지구변화는 산불 패턴에 변화를 야기하고 있다. 1991년부터 2008년까지 산불 발생과 기상 영향인자를 분석한 결과, 산불기간은 일찍 시작되어 점점 길어지고 있으며, 산불빈도는 평균온도, 상대습도, 강우와는 부의 관계가, 강우후 경과일수와 건조일 기간은 양의 관계가 있었다. 기후변화에 따른 산불관리 전략으로는 정확한 산불 원인 및 면적 통계에 따른 대상별 산불정책 개발 및 집행, 지역사회 기반 산불관리 정책 개발, 산불 근본 대책으로서의 숲가꾸기, 국제공조 등을 들 수 있다. 산불피해지 복원은 지역 주민의 경제적 수익과 더불어 산림생태계의 안정성을 도모하여야 한다.

서론(Introduction)

기후변화, 인구변화, 토지이용변화 등으로 초래된 지구변화는 과거 산불 패턴에 변화를 야기하고 있다. 전 지구적으로 대규모의 산불이 더 강하고 빈번하게 발생하여 지구촌 산림생태계와 인류의 건강을 위협하고 있다. 2011년 세계산불컨퍼런스에서는 지구변화, 지구온난화가 현실이고 지구적 산불 건수와 강도가 증가하며 사회에 미치는 영향이 점차 커지고 있다고 하였다. 이에 따라, 국가적, 지구적 차원의 보호(protection), 적응(adaption), 완화(mitigation)할 수 있는 적절한 산불정책과 전략을 개발하고, 경관 수준에서의 토지관리에 산불을 통합해야 한다고 하였다. 아울러 각국은 산불관리 평가, 법적 체계와 전략 구비, 지속가능한 산불관리능력과 조직 구성, 산불관리계획 수립과 인적 자원 개발을 지원해야 한다고 권고하였다.

지구온난화에 따른 기상이변으로 인한 산림재해의 대형화 등에 따라 산불 등 자연재해에 대한 예측기술의 개발이 필요하고 이에 대비, 대응할 수 있는 사회적 요구에 부응하기 위한 새로운 예방체계의 개발이 필요하다.

기후변화와 산불과의 연관성에 관한 최근 연구동향은 온도상승에 따른 CO_2 증가→온실가스의 증가로 인한 지구의 기후변화에 영향→산불발생과 피해규모 증가 예측→산불로 인한 지구온난화 가능성→자연생태계의 영향 등의 Feedback 시스템에 대한 다방면의 연구가 시도되고 있다.

이 논문에서는 한국에서 기후변화가 산불형의 변화에 미치는 영향을 고찰해보고, 우리나라의 앞으로의 이에 따른 산불관리 전략을 제시하고자 한다. 또한 산불피해지의 복원 전략을 논의하기 위해 장기간에 걸친 산불피해지 모니터링 결과를 제시하고, 이에 따른 복원 전략을 제시하고자 한다.

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1. 기후변화에 따른 산불전망

IPCC-WGⅡ에서는 기후변화로 인한 영향에 대해 극한 날씨의 강도와 빈도가 증가(2007.04.06. 제4차보고서)함을 밝혔다. 우리나라 또한 최근 이상고온, 건조 등 기후변화 영향으로 건조일수, 산림내 지피물 등 연소물질 증가 등으로 2000년 동해안(23,794ha), 2002년 청양 · 예산(3,095ha), 2005년 양양(1,141ha) 등 대형산불이 빈발하고 있다. 특히 겨울철 고온건조 현상으로 인한 가뭄현상이 나타나고 농경활동의 조기실시와 겨울철 야외활동 증가 등 산불발생 요인의 증가로 산불발생위험성은 더욱 높아질 것으로 전망됨에 따라 이에 대한 대책 연구가 필요하다.

산불 발생에 미치는 기후 조건을 파악하기 위해, 1991-2008년 동안의 산

불발생과 기상인자 사이의 상관관계를 분석하였다. 산불 발생에 미치는 기상 인자로 기후변화를 직접적으로 나타내는 변수인 기온, 산불발생을 억제하는 수분관련 변수들인 상대습도, 강수량, 무강수일수, 건조일 간격평균, 모두 5개의 인자를 분석하였다.

그 결과, 건조계절 산불발생은 1990년대에는 증가하고, 2000년대에는 감소하는 것으로 나타났고 1990년대의 경우, 기온, 무강수일수, 평균 건조일 간격이 증가하고, 상대습도, 강수량은 감소하였다. 1991-2008년의 건조계절 내 산불은 11월부터 증가하다가 2-4월에 급격한 증가를 보이고 5월에 급감하는 형태였다. 산불발생의 계절 내 변동은 4월까지 강수량 증가, 무강수일수 감소, 그리고 건조일 간격평균 감소가 산불발생에 작용하지만, 기온 증가로 인간 활동이 많아지고, 상대습도가 감소가 호조건으로 작용하여 산불발생이 급증하였다.

1990년대와 2000년대 계절 내 변동성을 비교해 본 결과, 2000년대 산불발생이 2월부터 시작하여 3월부터 빈번하게 나타나 4월까지 나타났다. 이는 이 시기 봄철 건조기가 평년보다 일찍 찾아온 점에서 비롯되었을 가능성이 있으며, 이는 산불기간이 길어짐을 의미한다.

서울・경기권역, 강원권역, 충청・호남권역, 영남권역으로 구분하여 기상인자와의 관계를 분석한 결과, 모든 권역에서 상대습도와 강수량은 줄었으며, 기온, 무강수일수와 건조일 간격평균은 권역에 따라 다소 차이가 있으나 전반적으로 늘어났다.

2. 산불발생 특성 변화에 따른 산불관리 전략

효과적인 산불전략을 수립하기 위해서는 무엇보다도 정책 토대가 되는 산불통계의 정확성이 요구된다. 10년 평균 연 478건의 산불 중 사실상 원인 불명으로 분류되는 입산자실화로 인한 산불이 43%을 차지하고 있다. 따라서 효과적인 산불 정책을 개발하고 집행하기 위해서는 이 43%에 대한 원인 조사가 분명하게 이루어져야 한다. 입산자실화에 대해 실제 그 원인을 조사한 결과, 약 절반 가량이 영농활동으로 인한 소각에 기인하였다. 이러한 측면에서 최근 산림청 산불방지과에 산불조사계를 설치하고, 산불전문조사반을 운영하여 발생 원인을 정확하게 구명하고자 하는 노력은 시의적절했다. 그러나, 예방차원에서 시군구 까지 강화활 필요성이 있다.

피해상황 통계와 관련되어 유엔 FAO 산하의 GOFC-GOLD (Global Observation of Forest and Land Cover Dynamics) 기구 내에 산불팀이 신설되어 위성영상을 활용하여 산불정보를 구축하고 있다. 향후 탄소배출과 관련된 피해면적 산정시 각국이 제출한 통계자료를 검증하는 단계까지 계획하고 있어, 국내에서도 각 지자체의 피해면적 통계를 검증하여 대응해야 한다.

지역 사회의 참여 없이는 성공적인 산불관리는 어렵다. 정확한 원인 조사를 통해 도출된 통계를 바탕으로 교육 대상별로 목적과 방법이 분명한 산불 사회 교육 프로그램이 개발되어야 한다. 한편 2011년 남아프리카공화국에서 개최된 산불컨퍼런스에서는 지역사회 기반 산불관리 정책이 주요 화두였다. 이는 즉 지역 사회의 이해와 참여를 기반으로 한 산불정책을 수립하고, 집행되어야 함을 의미한다. 컨퍼런스 성명서에서도 성공적으로 산불위험을 줄이고, 토지 및 환경의 생산성과 안전성을 증진시키기 위해서 참여형 접근법(participatory approaches), 지역사회 기반 산불관리(communities based fire management)을 통해 산불관리에 시민사회를 포함시켜야 함을 포함하고 있다. 이는 지역주민이 산불 정책에 있어서 대상자가 아니라, 정책의 개발자, 집행자로의 변화를 의미한다. 이를 위해서는 사회적 공감과 사회 교육이 필요한데, 지역 노인회를 위한 산불관리 프로그램을 개발하는 것은 소각행위자가 산불관리자가 된다는 측면에서 좋은 예이다.

초대형산불로 인한 산불의 강도가 강해지고, 산림인접지에 대한 개발이 증가하면서 주택과 인명피해가 점점 늘어나는 추세이다. 2009년 호주 검은 토요일 산불과 2002년 미국 콜로라도, 오리건, 뉴멕시코, 애리조나 일대에서 동시 다발로 발생한 산불은 산불에 강한 숲가꾸기의 중요성을 부각시켰다. 불의 확산속도와 강도 등에 미치는 인자는 일반적으로 지형과 연료(산림에 위치하고 있는 나무와 풀 등 유기물질)와 마지막으로 기상인자를 들 수 있다. 이 세가지 인자 중 우리가 산불에 대비하여 준비할 수 있는 인자는 연료뿐이다. 즉 산불이 천천히 타도록 하기 위해 사람의 힘으로 산의 급한 경사를 편평하게 할 수도 없을뿐더러, 바람의 세기와 방향 또한 우리의 힘으로는 바꿀 수 없다. 따라서 우리가 할 수 있는 최선의 방향은 산림을 산불로부터 피해를 줄일 수 있도록 가꾸는 것이다. 우리나라는 전 세계에서 부러워하는 조림 성공 국가이다. 이제 숲가꾸기 사업을 통해 산림이 건강하고, 동시에 산불에도 강한 숲으로 재탄생할 수 있도록 노력해야 한다.

대규모 산불의 빈번한 발생은 산불이 더 이상 한나라만의 문제가 아니라, 국제적인 이슈임을 말해준다. 이는 자원공유를 통한 공동진화, 전문화된 경험과 지식의 공유 등 국제협력의 강화가 필요하며, 그 수단이 개발되어야 함을 의미한다. 이를 위해서는 산불 관리와 산불 비상상황에 대한 상호 협조와 관련된 다자간, 양자간 합의가 이루어져야 하며, 산불관리에 있어서 경계를 뛰어넘는 협력에 대한 지구적 차원의 합의(Global agreement)가 도출되어야 함을 의미한다. 한편, 국제공조와 진화자원 공유를 위한 표준절차 및 매뉴얼 작성되고 있으므로, 적극적으로 참여해야 할 것이다.

결론적으로 2009년 호주 산불에서 도출된 결과와 비슷하게, 향후의 산불관리 전략은 진화자원 등의 하드웨어 확충도 좋지만, 지역사회 기반 산불관리

등의 사회교육 프로그램 개발과 확충된 진화자원을 효율적으로 이용하는 방안, 좀더 근원적인 해결책인 숲가꾸기 등 소프트웨어적인 측면을 보강해야 할 것이다.

3. 산불피해지 복원 과정 모니터링 결과

1996년 고성산불(3,762ha 소실)을 계기로 산불 피해로 인한 산림 생태계 영향 및 회복 과정을 구명하고 친환경적인 산불 피해지 복구 관리 기법을 개발하고자 고성, 강릉, 삼척, 울진 등지의 산불 피해지에서 생태계 변화 모니터링을 실시하고 있다. 산불피해지의 생태계 변화과정을 종합하면 다음과 같다.

가) 산불 후 대량 토사 유출은 3～4년간 지속되며 이를 억제하기 위하여 동해안 산불 피해지에 대해서는 산불피해를 받아 벌채한 통나무를 산지 사면에 수평쌓기를 실시토록 하였다. 그 효과는 편책공을 설치하는 것과 비슷한 토사유출 억제효과를 나타냈으며 통나무를 쌓음으로서 야생동물의 서식처로도 이용되었고 결국 참나무류의 맹아가 자라 지력 향상을 촉진시키는 효과를 가질 것으로 추정된다.

나) 산불 피해지는 전소된 곳과 지표화 피해를 받은 임분 등이 섞여 모자이크상의 모양을 나타낸다. 전체적인 식생 변화는 초기 화본과 식물에 의한 초지화가 이루어지며 3~4년이 경과하면 싸리 등의 관목과 참나무류 맹아가 섞여있는 관목림 상태로 바뀌고 5~6년이 경과하면 아교목층과 관목층의 층 분화가 이루어진다. 자연복원시킨 경우 남사면은 굴참나무가 북사면은 신갈나무가 우점하는 경향을 보였다.

다) 곤충, 야생동물(포유류, 조류) 등의 변화는 식생의 회복 정도에 따라 초지성 종에서 점차 산림성 종으로 변화하는 모습을 보였다. 나비의 경우 산불 당해년도에는 초지성 나비가 많아졌다가 점차 감소하며 임연부 서식 나비는 점차 증가하였다. 메뚜기군집의 경우 수목류가 증가함에 따라 메뚜기아목은 줄어들고 여치아목은 증가할 것으로 예상된다. 조류의 경우 산불 발생 후 초기에는 개활지 선호종이 대부분이며, 일부 생육하고 있는 교목에서 박새류가 관찰되었다.

라) 이동성이 강한 어류는 산불 후 3년간 모니터링한 결과 산불의 영향이 없는 것으로 나타났으나 저서성대형무척추동물의 경우에는 재, 낙엽, 토사퇴적 등 계류 상태에 따라 다양한 변화과정을 겪지만 연수가 경과함에 따

라 꾸준히 증가하는 추세를 보였다.

마) 수목병원균상을 조사한 결과, 참나무류에는 녹병, 튜바키아점무늬병, 흰가루병 등 다양한 병해가 계속 발생되는 것으로 조사되었으며, 병해 피해로 인해 수고나 생장이 다른 지역 참나무에 비해 적은 것으로 조사되었다. 송이균 생존률은 48%에 달하였다. 강릉, 삼척 산불피해지에 미생물제제를 처리한 결과, 처리구와 대조구를 비교했을 때 대부분의 토양 특성이 처리구가 대조구에 비해 양호하게 나타났다.

바) 경관생태기법을 적용한 복원전략 수립을 위하여 피해지 복원을 위한 경관지수(CBI)를 선정하였으며 피해지 복원을 위해 인공위성사진(RS, NBR)를 기본경계로 설정하는 방법을 연구하였다.

이러한 생태계 변화과정에 대한 모니터링 결과는 산불피해지의 식생변화 조건에 따라 어떠한 복원과정을 적용할 것인지를 결정하는데 중요한 인자로서 임분이 정상적인 임분의 상태에 도달하는 단계까지 지속적인 관찰을 실시할 예정이다

4. 향후 산불피해지 복원 관리 전략

산불피해지 복원은 산주 및 지역 주민의 경제적 수익을 전제하지 않을 수 없다. 따라서 목재 이외의 단기소득자원의 조성에 대한 고려를 해야 한다. 반면에 산림생태계의 안정성을 도모하여야 한다. 이는 국가적 차원에서 해당 피해지역에서 유지되어야할 생물자원량으로 산정하는 기준치(현재는 없음)에 조기 도달할 수 있도록 노력하는 것이다. 한편 대형산불의 재발을 억제하기 위한 내화수림대의 조성, 내화성 임분 개량 등의 대한 노력도 경주하여야 한다. 2000년 동해안산불피해지 복구 시 적용한 경관조림지는 경관적 가치 창출뿐만 아니라 산불강도를 완화시켜 주요 시설을 보호할 수 있는 수단도 된다. 또한 인공위성사진(RS, NBR)을 활용함으로써 보다 신속하고 정확한 피해지 구획과 피해 평가 시스템 구축이 필요하다. 향후 복원전략을 수립할 때에는 산림의 구조를 계량적으로 평가할 수 있으며, 산림의 생태적 기능과 밀접한 관계를 보이는 경관생태지수에 기반한 경관생태기법을 적용해야 할 것이다. 즉 산불 전의 경관구조 상태를 기준으로, 복원시 이와 유사한 경관구조를 갖도록 조성 또는 유도해야 할 것이다.

훼손된 산림생태계는 자연회복력에 의해 현재 환경에 적합한 수준으로 적응하며 점차 천이과정이 이루어질 것이다. 따라서 입지 조건이 양호한 곳에

서는 식생과 여기에 기반을 둔 생물, 무생물도 순차적으로 회복되어 정상 임분이 될 것이다. 하지만 질적인 면에서 살펴보자면 목재 생산성의 저하와 심재부후 등의 문제가 도출된다. 따라서 이런 지역에서는 지위조건에 따라 목재 생산림은 우선 맹아림 유도후 수종 갱신으로 건전임분 유도가 가능하다. 그러나 척약지의 경우에는 자연력에만 의존하기에는 시간이 오래 소요되므로 우선적으로 식생이 정착할 수 있도록 토양 안정화 작업이 우선적으로 필요하다.

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ORAL PRESENTATION II

Effects of disturbance intensity on arthropod communities in burned pine forests in Korea

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Abstract

Forest fires are one of the most frequent and important causes of forest disturbances, and they are gradually increasing due to climate change. This study aimed to find their impact of fire and human activity on arthropod communities in burned forests. Twelve study sites in three burned areas were selected for this study. Intensities of disturbance in the study sites were characterized as follows: 0 (no fire), 1 (weak fire), 2 (strong fire), and 3 (strong fire followed by human disturbance). Arthropods were collected using pitfall traps. Fourteen arthropod taxa (families, orders or classes) which are relatively homogeneous in feeding habits and abundant, were analyzed. Depth of litter layer was selected as an environmental indicator for disturbance intensity because it decreased linearly as degree of disturbance increased. Change of arthropod abundance in response to disturbance differed among functional guilds. As disturbance intensity increased, abundance of detritivores decreased, but herbivores increased. However, abundance of predators varied between taxa. Formicidae and Araneae abundance increased in disturbed sites, whereas Carabidae and Staphylinidae did not change. Abundance of Thysanura and Diptera was most highly correlated with disturbance intensity and may be used as a bioindicator for forest disturbance. Arthropod communities were more diverse in forests of intermediate disturbance.

Introduction

Forest damages have increased due to climate change. For example, climate change has been linked to increased wind damage (Peterson 2000; Peltola et al. 2010), landslides (Kim and Chae 2009), tree mortality (Allen et al. 2010), bark beetle outbreak (Walton et al. 2008), and mega forest fires (Beverly and Martell 2005). In Korea, various environmental disturbances, including forest fires, have steadily increased due to climate change (Lim et al. 2006). Due to successful reforestation in South Korea, combustibles, such as leaf litters, dead branches and wood have accumulated in forests, resulting in an increased risk of mega forest fires. In late April 1996, a large fire burned 3,672 ha of forests in Goseong in Gwangwon province (Korea Forest Research Institute 1997). In April 2000, the largest fire recorded in Korea burned 23,794 ha of forests across Goseong, Gangneung, Samcheok in Gwangwon province and Uljin in Gyoungbuk province. It caused serious disturbance of forest ecosystems and economic damage in the local communities (Ro et al. 2000).

Various disturbances play important roles in the formation of the structure and in the function of ecosystems. Moderate disturbances promote heterogeneity of habitat and increase biodiversity through migration of organisms (Kwon and Park 2005; Noske et al. 2008). Gaps in forests created by fire or wind produce different microenvironments and vegetation structures from surrounding and support overall high species diversity (Lain et al. 2008). In addition, dead wood created by disturbance provide habitats and food for various organisms (Lachat et al. 2006; Gibb et al. 2006). After the mega fire in 2000, homogeneous landscapes composed of pine forests (*Pinus densiflora*) were replaced with diverse landscape mosaics (Choung et al. 2004). To increase biodiversity in forests, moderate disturbances, such as prescribed fire, clear cutting, and thinning, were artificially applied (Gondard et al. 2003; Glasgow and Matlack 2007; Kwon et al. 2010a; Maleque et al. 2010).

In Korea, reforestation of burned forests has been usually applied for recovery of burned forests. After the mega fire in 2000, however, natural regeneration of vegetation was suggested for recovery of the burned areas (Choung et al. 2004). After debate, both types of regenerations were used for recovery of burned forests. Prior to reforestation, dead trees and branches were logged and small trees and shrubs were removed, leading to increased disturbance to burned forests. However, to our knowledge, no study has been conducted to investigate the impact of fire intensity and reforestation on arthropod communities. Arthropods are important components of forest ecosystems. They perform a variety of ecosystem functions, including nutrient cycling, pollination, litter decomposition, and density control (Kremen et al. 1993; Niemelä et al. 1996;

Triplehorn and Johnson 2005). They respond rapidly to ecosystem changes because of their short generation time, high mobility, and dependence on temperature (Kremen et al. 1993; Samways 1994; Schowalter et al. 2003; Maleque et al. 2009). Hence, arthropods are useful bioindicators to estimate the impact of various disturbances, such as climate change, forest thinning, and insecticides (Schowalter et al. 2003; Yi and Moldenke 2008; Kwon TS 2008; Kwon et al. 2010b).

Ground fires (hereafter weak fire) mainly burn understory vegetation, whereas crown fires (hereafter strong fire) burn all vegetation. Thus, the effect of fires on forest ecosystems depends greatly on their intensity (Whelan 1995). As noted above, it is expected that arthropods may be further affected by reforestation of burned forests. This study aims to evaluate the impact of disturbance intensity due to fire and reforestation on arthropod communities in burned forests. Arthropod communities were compared among four disturbance intensities (no fire, weak fire, strong fire, and strong fire followed by reforestation) in three burned areas.

Materials and methods

Study sites and disturbance degree

This study was carried out in three burned areas (Goseong, Gangneung, and Samcheok) in the north-eastern coast region of South Korea (Fig. 1). Forests in the north-eastern coast region are composed mainly of pine forests and have most frequently experienced forest fires in South Korea due to a strong and dry northeasterly wind in early spring. Forests of 3,672 ha in Goseong were burned on 23 to 25 April in 1996 (Korea Forest Research Institute 1997).

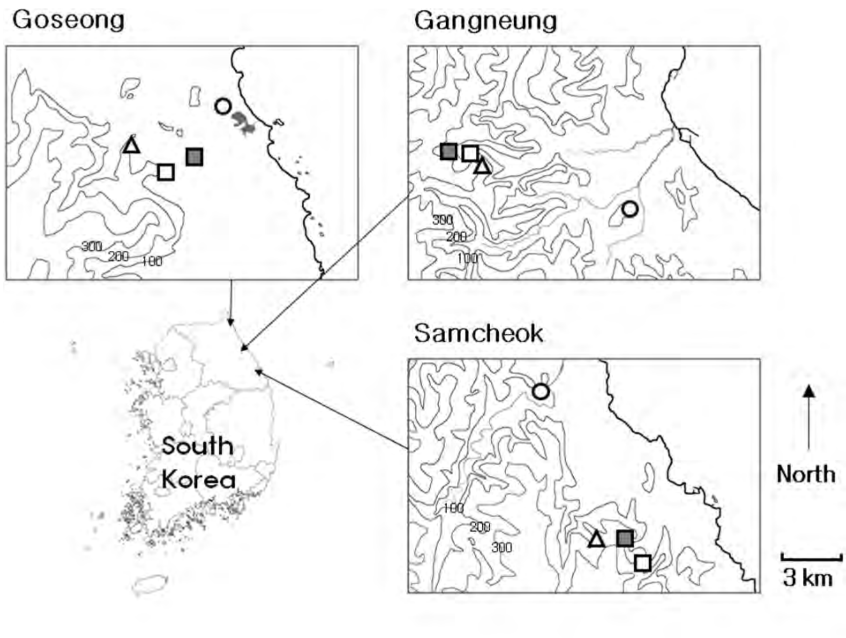

Fig. 1. Study sites. Circle: unburned site in pine forest (Disturbance Degree, DD = 0), triangle: site in pine forest burned by weak fire (DD = 1), open rectangle: site burned by strong fire (DD = 2), dark rectangle: site burned by strong fire and reforested afterward (DD = 3). Estimation logic for DD is shown in text.

This fire was started accidentally during army training and the economic loss was about $1,800,000. In April 2000, a very large fire burned forests of 23,794 ha in four counties, including Goseong, Gangneung, Samcheok, and Uljin. It was the largest recorded fire in Korea and it burned 0.37% of the total forest in South Korea (Ro et al. 2000). In April 2004, a medium fire burned pine forest of 430 ha in Gangneung.

A total of 12 study sites (4 study sites in each of 3 burned areas) were selected for this study (Fig. 1). Disturbance intensity was characterized as one of four disturbance degrees (hereafter DD). DD of unburned pine forest was 0, and DD after a weak fire was 1. DD after a strong fire was 2, and DD after a strong fire followed by reforestation was 3.

The average annual temperatures in Goseung, Gangneung, and Samcheok in 2005 were 11.9˚C, 12.9˚C, and 12.1˚C, respectively (Korea Meteorological Administration 2005). Annual rainfall in 2005 was 1,349 mm in Goseong, 1,650 mm in Gangneung, and 1,433 mm in Samcheok. Study sites are located 1 to 12 km from the coast, and at elevations of 20 to 192 m. Site aspects are north (8 sites), south (2 sites: Samcheok, DD 2 and 3), east (Donghae, DD 2), and west (Goseong, DD 1). In Goseong, DD 2 and 3 were located at N38^{o}18', E128^{o}29', DD 1 at N38^{o}19', E128^{o}27', and DD 0 at N38^{o}20', E128^{o}30'. In Gangneung, DD 1 to 3 were located at N37^{o}36', E129^{o}01', DD 0 at N37^{o}35', E129^{o}01'. In Samcheok, DD 1 to 3 were located at N37^{o}14', E129^{o}16-18', and DD 0 at N37^{o}20', E129^{o}14'. Site slopes were mostly 3 to 30^{o} and 2 sites (DD 2 and 3) in Samcheok were steep (ca. 50^{o}). Soils at study sites originated from granite, and soil textures were silt loam, loam, or sand loam. Red pines (*Pinus densiflora*) of about 30-40 years old were the main trees in DD 0 or 1 in 3 study areas. Shrubs and herbs were growing moderately under pine trees. No or a few pine trees were found in DD 2 or 3. Shrubs and herbs were growing well in understory vegetation there.

Vegetation, litter and soil property

Vegetation at the study sites was investigated by a botanist (Dr. Ryu) who recorded the plants growing in a plot of 450 m^2 (width 10 m, length 45 m) where pitfall traps were set up. To estimate vegetation structure, the coverage (%) of the tree, sub-tree, shrub, and herb layers were estimated. Depth of the litter layer was measured in 10 replicates per plot (450m^2), and the average of the values was used for analysis. Five soil samples (ca. 100 ml) per plot were randomly sampled from the surface to a depth of 5 cm depth using a small shovel after removing the litter layer and samples were pooled for each plot. Soil samples were analyzed in the soil analysis laboratory of the Korea Forest Research Institute for estimation of pH, soil texture (i.e., composition of sand, fine sand, and silt), organic matter, total nitrogen, and cation exchange capacity ($cmol_c$/kg).

Arthropods sampling

Arthropods were collected in pitfall traps consisting of a plastic cup (depth 6.3 cm, mouth diameter 8 cm, bottom diameter 6 cm). Twenty pitfall traps were buried at each study site for 10 days in late May 2005. The survey period is considered best for sampling of arthropods since arthropods are active and abundant in this high temperature and low rainfall season from late May to early June in Korea (Kwon et al. 2005; 2010a). For 10 days, each of 20 traps was placed 5 m apart from adjacent traps along two parallel lines about 10 m apart. Each trap was filled about one-third with ethylene glycol as a preservative. All arthropod specimens were isolated from debris in the laboratory, stored in 80% ethyl alcohol, and identified to order or family level using taxonomic keys (Choi 1996; Triplehorn and Johnson 2005) under a stereomicroscope. All the specimens were deposited in the Insect Specimen Storage Room of the Korea Forest Research Institute.

Functional guilds of arthropods

Microarthropods, such as springtails and mites, were excluded from analysis because of high variability of abundance (Kwon 2008). Arthropods that have relatively homogenous feeding functions at the coarse taxa (i.e. family, order, or even class) level were used for analysis. Crustacea, Thysanura, and Diplopoda are representative detritivores. Diplopoda were not used in analysis due to low abundance (Table 1). Although Diptera have several feeding functions, they are mainly detritivores. Orthopterans were assigned into two groups: detritivores (Othroptera-D) and Herbivores (Orthoptera-H). Othroptera-D included Rhaphidophoridae, Gryllidae, and Gryllotalpidae, whereas Othroptera-H included Acrididae, Tettigoniidae, and Tetrigidae.

Sap-feeding Homoptera were assigned into two groups: Aphididae and other Homoptera. Aphididae are relatively abundant and different in life cycle and habit compared with other Homoptera. Larvae of Lepidoptera were classified as herbivores. Hemiptera were excluded from analysis because they include both predators and herbivores. Four coleopteran families, Carabidae, Staphylinidae, Curculionidae, and Chrysomelidae, were used. Carabidae and Staphylinidae were grouped as predators, while Curculionidae and Chrysomelidae were grouped as herbivores. Of the hymenopterans, only Formicidae (ants) as predators were used. Other Hymenoptera were not used due to their diverse feeding functions (i.e., herbivore, parasites or predators). Araneae (spiders) were used in analysis as predators. Chilopoda are predators but were not used because of low abundance. Opiliones were abundant (Table 1), but were not used because they include both predators and detritivores (Triplehorn and Johnson 2005). Blattaria may not be specific to forests so they were not used for analysis.

Statistical analyses

The number of arthropod individuals collected per trap was log transformed (ln N+1) to reduce variance. ANOVA was used to find differences in abundance of arthropods or in values of environmental factors according to scales of DD, and Neuwman-Keuls multiple comparison test was used afterwards. As litter depth decreased linearly with increasing scales of DD (see Results). it was used as a representative factor for intensities of disturbance. Regression analysis on each arthropod group was performed using litter depth as the independent variable. Multidimensional scaling (MDS) using Euclidean distance was used for ordination of arthropod communities. MDS ordination was conducted using PC-ORD (ver. 5.17) (McCune and Mefford 1999), and the other analyses were performed using STATISTICA (Statsoft 2004).

Results

Abundance (i.e., number of individuals) of the arthropods collected in the three study areas is presented in Table 1. A total of 23,131 arthropods (except springtails and mites) belonging to five Classes were collected. The numbers of arthropods collected were 8,742 in Goseong, 7,503 in Gangneung, and 6,666 in Samcheok. Abundance decreased from north to south (Fig. 1).

Table 1. Number of individuals of arthropods collected in pitfall traps Microarthropods such as springtails and mites were not included in table.

Class	Order	Family (Function, et al.)	Study area Goseong	Gangneung	Samcheok	Total	Proportion (%)	Function
Crustaceae			22	96	20	138	0.6	Detritivore
Arachnida	Araneae		2,048	1,621	713	4,382	18.9	Predator
	Opiliones		5	289	14	308	1.3	
Insecta	Microcoryphia		89	51	195	335	1.4	Detritivore
	Blattaria		70	19	136	225	1.0	
	Isoptera		26	1	1	28	0.1	
	Orthoptera	(Herbivore)	48	82	27	157	0.7	Herbivore
		(Detritivore)	29	23	27	79	0.3	Detritivore
	Hemiptera		21	17	11	49	0.2	
	Homoptera	Aphididae	56	174	15	245	1.1	Herbivore
		(Other)	90	43	29	162	0.7	Herbivore
	Hymenoptera	Formicidae	3,651	1,888	2,990	8,529	36.9	Predator
		(Other)	323	208	335	866	3.7	
	Lepidoptera	(Larvae)	48	48	24	120	0.5	Herbivore
	Coleoptera	Carabidae	59	151	29	239	1.0	Predator
		Staphylinidae	29	527	65	621	2.7	Predator
Insecta	Coleoptera	Chrysomeridae	8	76	17	101	0.4	Herbivore
		Curculionidae	41	95	188	324	1.4	Herbivore
		(Other)	353	677	287	1,317	5.7	
	Diptera		1,670	1,342	1,661	4,673	20.2	Detritivore
	(Other)		38	36	51	125	0.5	
Diplopoda			2	16	37	55	0.2	
Chilopoda			16	23	14	53	0.2	
Total			8,742	7,503	6,886	23,131	100.0	

Formicidae was most abundant, representing 37% of total. Diptera (20%), Araneae (19%), and Coleoptera (11%) were also abundant. Opliones, Blattaria, and Hymenoptera (except Formicidae) were not used in this analysis, but were relatively abundant (1-4%). In Table 1, groups with feeding functions were used for analysis and accounted for 87% of total arthropods.

When abundance of arthropods analyzed were compared among the four DDs, Thysanura, Orthoptera-H, and Homoptera (other) abundance were significantly different ($p < 0.05$), whereas Diptera was marginally significantly different ($p = 0.054$) (Table 2). As DD increased, detritivorous Thysanura and Diptera decreased linearly, whereas the herbivorous Homoptera increased. Abundance of the herbivorous Orthoptera-H was not linearly related with DD, but was higher in high DD (2 and 3) than in low DD (0 and 1).

Table 2. Number (ln n+1) of arthropods according to disturbance degree (DD) in the study sites. Details on DD are shown in text and Table 1. The different letters behind SE indicate significant difference ($p < 0.05$) between groups according to Newman-Keuls multiple comparison test.

Function	Taxa	Disturbance Degree 0		1		2		3		ANOVA-test (df = 3, 8)	
		Mean	SE	Mean	SE	Mean	SE	Mean	SE	F	p
Detritivore	Crustacea	0.55	0.25	0.65	0.25	0.23	0.14	0.12	0.09	1.7	0.24
	Thysanura	1.32	0.26a	1.01	0.41ab	0.33	0.17ab	0.05	0.05b	5.2	0.03
	Diptera	3.42	0.25	3.14	0.23	2.65	0.19	2.30	0.32	3.9	0.054
	Orthoptera-D	0.13	0.03	0.36	0.22	0.35	0.11	0.20	0.12	0.7	0.595
Herbivore	Orthoptera-H	0.14	0.02ac	0.17	0.04a	0.80	0.25b	0.64	0.11bc	5.7	0.022
	Homoptera (other)	0.17	0.01a	0.31	0.05ab	0.29	0.12ab	0.98	0.23b	7.7	0.01
	Aphididae	0.34	0.14	0.80	0.33	0.53	0.33	0.69	0.36	0.4	0.726
	Lepidoptera (larvae)	0.25	0.07	0.24	0.08	0.45	0.12	0.60	0.13	3.0	0.098
	Chrysomeridae	0.20	0.11	0.14	0.07	0.44	0.36	0.37	0.21	0.4	0.729
	Curculionidae	0.41	0.11	1.15	0.48	0.70	0.08	0.56	0.21	1.4	0.321
Predator	Araneae	2.45	0.09	2.89	0.31	3.00	0.45	2.99	0.30	0.7	0.585
	Carabidae	0.63	0.04	0.88	0.41	0.60	0.30	0.22	0.06	1.1	0.395
	Staphylinidae	0.70	0.33	1.24	0.70	1.08	0.71	0.37	0.14	0.5	0.665
	Formicidae	2.85	0.12	3.09	0.56	3.61	0.08	3.99	0.35	2.3	0.153

When vegetation and soil variables were compared among DDs, tree coverage and litter depth were significantly different ($p < 0.05$), and shrub coverage, organic matter, and CEC were marginally significantly different ($p < 0.1$). Tree coverage and litter depth decreased with increasing DD. Organic matter in DD 0 and 1 was 3.3 to 3.5, whereas in DD 2 and 3 it was 1.5 to 1.7. CEC was higher in DD 0 and 1 (10 to 11.4) than in DD 2 and 3 (7 to 8). Although soil texture (i.e. composition of soils) was not significantly different among DDs, its change may be related to the loss of fine soils at burned sites. Sand increased with increasing DD, but fine sand and silt decreased. These results show that severe disturbance led to loss of soil, litter layer, organic matter and CEC.

Because litter depth decreased linearly along with increasing DD, it may be an environmental indicator to intensities of disturbance (Table 3). The abundance of the four taxa which were significantly different in Table 1 was arranged along litter depth (Fig. 2). Thysanura, Diptera, Lepidoptera (larvae), and Formicidae were significantly correlated with litter depth ($p < 0.05$). In regression analysis using litter depth as an explaining variable, it explained about 33 to 70% of total variations (R^2 of Thysanura = 0.70, Lepidoptera = 0.60, Diptera = 0.49, and Formicidae = 0.33). However, abundance changed differently among feeding guilds. Abundance of the detritivorous Thysanura and Diptera increased as litter depth increased, whereas the herbivorous Lepidoptera and the predatory Formicidae decreased.

Table 3. Variables of vegetations and soils according to disturbance degree in the study sites. Details on degree of disturbance are shown in text and Table 1. The different letters behind SE indicate significant difference ($p < 0.05$) between groups according to Newman-Keuls multiple comparison test. .

	Factor	Disturbance								ANOVA (df = 3, 8)	
		0		1		2		3			
		Mean	SE	Mean	SE	Mean	SE	Mean	SE	F	p
Vegetation	Tree coverage (%)	76.7	3.3a	46.7	12.0a	6.7	6.7b	3.3	3.3b	23.16	0.0002
	Sub-tree coverage (%)	3.3	1.7	30.0	17.3	13.3	13.3	0.0	0.0	1.51	0.284
	Shrub coverage (%)	15.0	7.6	40.0	20.8	70.0	17.3	11.7	4.4	3.60	0.065
	Herb coverage (%)	66.7	8.8	61.7	16.9	26.7	6.7	70.0	15.3	2.50	0.134
	No. of species	37.0	6.4	32.3	2.6	25.0	1.5	31.0	4.2	1.44	0.301
Soil	Depth of Litter depth (cm)	3.6	0.6a	2.3	0.4ab	1.5	0.4ab	0.8	0.3b	6.93	0.013
	Sand (%)	39.3	4.8	51.6	9.7	59.6	16.8	67.6	4.1	1.41	0.311
	Fine sand (%)	42.6	4.3	34.6	7.0	28.2	12.1	22.3	2.2	1.38	0.318
	Silt (%)	18.1	2.7	13.8	4.0	12.2	4.7	10.1	1.9	0.96	0.458
	pH	5.4	0.3	5.8	0.6	5.7	0.4	5.8	0.3	0.20	0.890
	Organic Matter (%)	3.3	0.6	3.5	0.6	1.7	0.5	1.5	0.1	3.92	0.054
	Total nitrogen (%)	0.4	0.2	0.2	0.0	0.1	0.0	0.1	0.0	1.60	0.263
	CEC (cmol+/Kg)	10.0	1.0	11.4	1.6	8.0	0.6	7.0	0.5	3.96	0.053

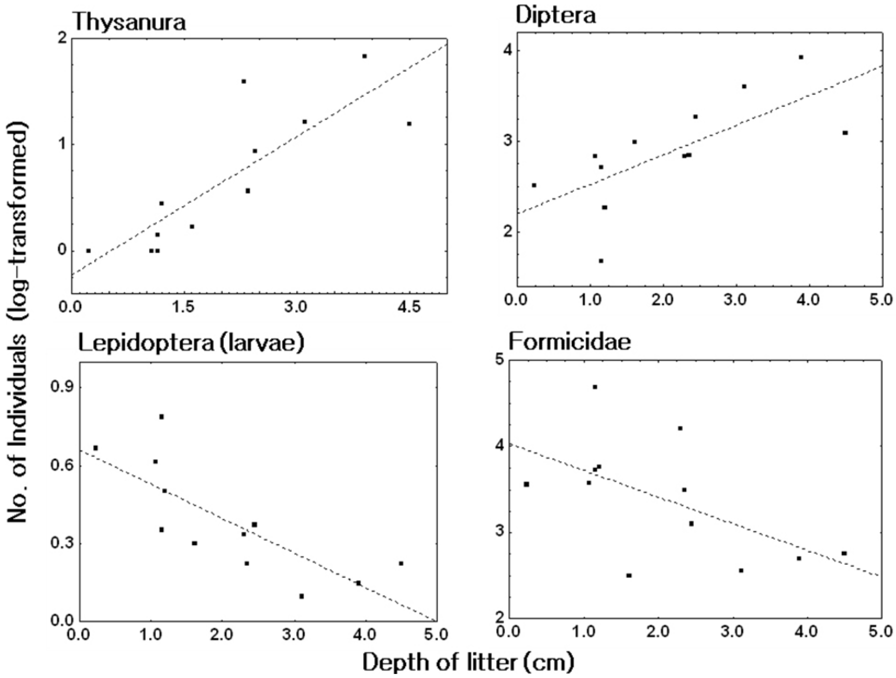

Fig. 2. Log (ln n+1) transformed abundance (individuals collected at a pitfall trap) of arthropods according to depth of litter. The selected arthropods show significant ($p < 0.05$) or marginally significant ($p < 0.1$) differences among scales of disturbance degree (DD).

When beta values of all taxa in the regression analysis were compared, general relationships between feeding guilds and litter depth appeared (Fig. 3). The herbivorous taxa had negative beta values ranging from -0.05 to -0.21, whereas the detritivorous taxa had positive beta values ranging from 0.004 to 0.43. The predatory Fomicidae (-0.31) and Araneae (-0.22) had negative beta values, but the predatory Staphylinidae (0.005) and Carabidae (0.02) had beta values near 0. Beta values were significantly different among three functional guilds (Kruskal-Wallis nonparametric ANOVA, H = 6.5, $p < 0.05$). Such results were also confirmed when abundance of 14 taxa were pooled into three feeding guilds (Fig. 4). Abundance of all three feeding guilds was significantly correlated with litter depth ($p < 0.01$). The beta value of detritivores was 0.37 with $R^2 = 0.54$, of herbivores was - 0.37 with $R^2 = 0.51$, and of predators was - 0.29 with $R^2 = 0.52$. Predators might have a negative beta value due to the negative value of abundant Formicidae and Araneae.

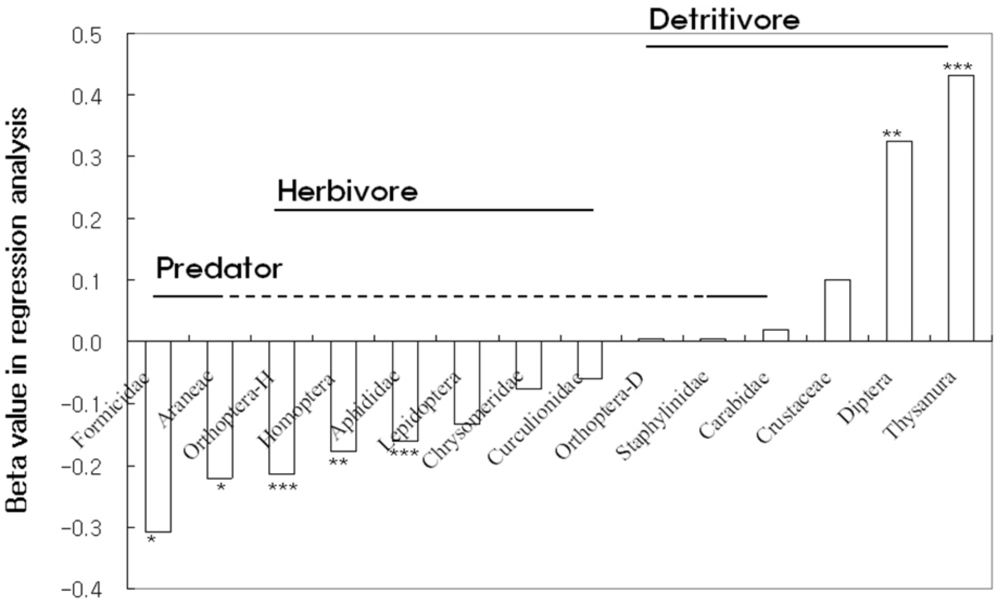

Fig. 3. Beta value of 14 taxa in regression models using litter depth as independent variable. Significance of regression models (i.e., beta value of regression model is not zero) are represented as follows; * p < 0.01, ** p < 0.05, and *** p < 0.01.

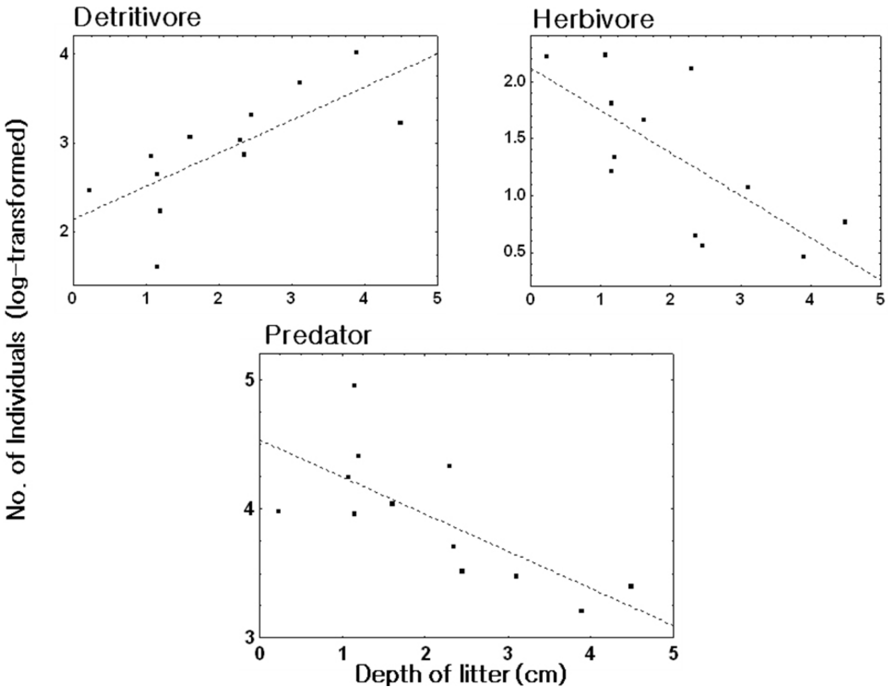

Fig. 4. Log (ln n+1) transformed abundance (individuals collected at a pitfall trap) of three feeding guilds according to depth of litter. Feeding guilds of 14 taxa are shown in Table 1.

The above results can be comprehensively summarized by MDS ordination (Fig. 5). In MDS ordination, Axis I (55%) and Axis II (40%) explained 95% of total variation. Angle of original ordination was moved slightly for visualization. Communities of arthropods were sequentially arranged according to scale of DD along Axis II. Arthropod communities in the least disturbed sites (DD 0) were closely located in the uppermost part of Axis II, whereas largest disturbed sites (DD 3) were closely located in the lowest. Moderately disturbed sites (DD 1 and 2) were located in the middle part of Axis II. Distances between sites are longer in moderately disturbed sites than in un-disturbed or highly-disturbed sites. This result indicates that moderate environmental disturbance contributes to greater diversity of community structure.

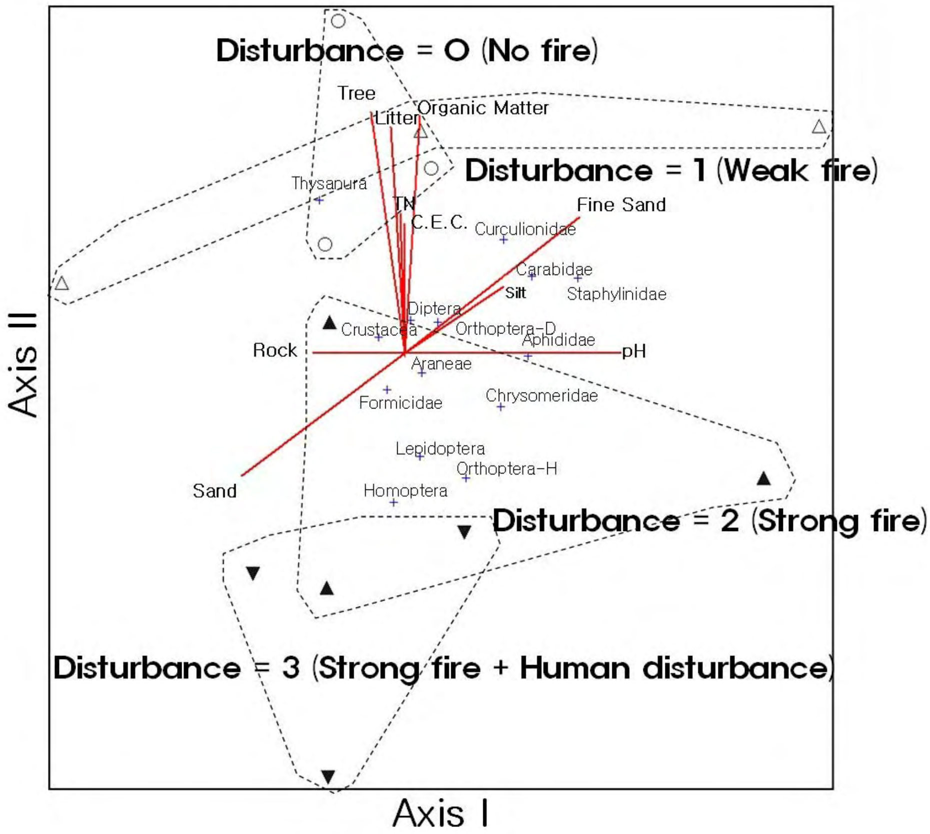

Fig. 5. MDS ordination of arthropod communities. Two axes explain 95% of total variation. Angles of two axes were moved slightly for visualization of arthropod communities according to disturbance degree (DD). Circle: unburned site in pine forest (DD = 0), open triangle: site in pine forest burned by weak fire (DD = 1), dark triangle: site burned by strong fire (DD = 2), and reversed dark triangle: site burned by strong fire and reforested afterward (DD = 3).

Directions and scales of vectors of environmental variables almost coincided with the results shown in Table 3. The vectors of tree coverage, litter depth, and organic matter showed the same direction as arthropod communities of DD 0, showing their negative relationships with DD. TN and CEC also displayed the same direction. The vector of sand had the same direction as DD 3, whereas fine sand and silt had the reverse direction. This shows that coarse soils are positively correlated with scales of DD but fine soils are negatively correlated with DD. The arrangement of 14 taxa in Axis II was significantly correlated with the beta values in Fig. 3 (Spearman rank correlation, $r = 0.73$, $p < 0.05$). Homoptera, Lepidoptera, Formicidae, and Araneae, which have negative beta values, were located in the lower part of Axis II, whereas Thysanura, Diptera, and Crustacea, which have positive beta values, were located in upper part of Axis II.

Discussion

The expected patterns, including decrease of litter layer, loss of fine soils and nutrients supporting growth of plants, are recognized by present study. However, the content of nutrients in soils temporally increased in early stage of forest fire. Immediately after forest fire in Goseong in 1996, Ca, K, and Mg concentrations were higher in burned forests, whereas organic matter and nitrogen concentrations were not changed (Mun and Choung 1996). Oh et al. (2001) reported that organic matter and nutrient concentrations were higher in one of two burned sites for 10 months compared to the control site, but was lower after 11 months. However, one burned site had continually higher concentrations. In our study sites, nutrients were more abundant in unburned site than in burned sites at all times. Loss of soil and nutrients in burned forests may differ due to various environmental factors such as vegetation and topography (Choung and Kim 1987; Edmonds et al. 2000; Oh et al. 2001). Large amounts of ash produced by the 2000 mega fire polluted streams and the sea. Accordingly, the outflow of soils and nutrients caused by forest fires may significantly influence the surrounding ecosystems.

In forest ecosystems, leaf litters plays key roles in material recycling, control of surface microenvironment, outflow restraint of sediment and soil nutrient, and influencing inhabitants such as microbes and arthropods (Lee et al. 2004). The decline of litter layer was related linearly with intensity of disturbance caused by forest fire and artificial disturbance. Abundance of detritivores linearly decreased as depth of litter layer decreased. It is likely that detritivores feeding on litters can be useful bioindicators for determining forest disturbance. By 10 years after a forest fire in eastern Australia, mouse density increased logarithmically with increasing litter (Fox and Matzner 1987). Lee et al. (2006) found that density and weight of rodents were higher in natural recovery sites (DD 2) than in reforestation sites (DD 3) because natural recovery sites may provide a better habitat (coarse woody debris and understory vegetation) for rodents. More litter dwelling arthropods inhabited in natural restoration sites versus reforested sites which may explain the success of rodents.

Thinning of *Pinus koraiensis* planatation reduced litter layer, resulting in a decrease of the detritovorous Diptera (Kwon et al. 2010a). In Argentina, the abundance of Diptera was much lower in logged shrub forest compared with dry forest (Molina et al. 1999). Such results show the similar impact of environmental disturbance caused by thinning and forest fire. However, Diptera belong to other feeding guilds in addition to detritivore guid. In Korea, dipterans collected by pitfall trapping at 60 sites in 12 high mountains were classified based on feeding guilds in family level. Among 50 feeding guild defined families of 61 total families, 25 families belonged to the detritivores (50%), followed by herbivores (18%), predators (6%), parasites (5%), and aquatic inhabitants (5%). However, at the individual level, 91 % were detritivores, followed by herbivores (6%), predators (0.8%), aquatic inhabitants (0.8%), and parasites (0.7%) (Kwon unpublished). Thus, grouping of Diptera as detritivores may not be far from a reality. Although Crustacea, Thysanura, and Orthoptera-D have homogenous feeding habits that are dependent on leaf litter, their abundance changed differently depending of various environmental disturbances caused by thinning or forest fire (Yi and Moldenke 2008; Kwon et al. 2010a). These arthropods may not be abundant enough to reflect a stable pattern related with disturbances. Many dipterans inhabit in leaf litter and soil in temperate forests of the Eurasian continent (Hovemeyer 2000), and the litter layer was the most important factor affecting the development of soil dwelling dipteran larvae (Frouz 1997). Therefore, Diptera has a high possibility for use as a bioindicator for various environmental disturbances related with the loss of litter layer (Kwon et al. 2010a).

In this study, herbivores were positively correlated with intensity of disturbance (i.e., reciprocal to litter depth) because herbivores obtain food and live in herbs or shrubs which grow after the destruction of trees. However, Bae et al. (2011) reported that species richness and abundance of moths collected using light traps in Samcheok from 2006 to 2009 were highest in unburned site (DD 0), followed by surface fire site (DD 1), and lowest in crown fire site (DD 2). This pattern is opposite of ours. The reason for this difference is not clear but it may be due to different study methods. The present study was carried out in three areas for one season, whereas that of Bae et al. (2011) was carried out in one area for a longer period. In butterfly fauna surveyed from 2005 to 2010 in Samcheok, species richness and abundance were higher in burned forests than in unburned well-conserved forests (Kwon unpublished). This agrees with our results but disagrees with those of Bae et al (2011). However, in butterfly data in Uljin for 3 years, abundance and richness did not differ between burned and unburned forests (Kwon unpublished). It may not be correct to conclude general patterns using data collected from restricted areas due to the high spatial variation of arthropod communities. Herbivores may respond differently to changes in the vegetation structure caused by environmental disturbances. Herbivores feeding on herbs and shrubs may increase after forest destruction, whereas herbivores feeding on trees may decrease. However, the latter may increase with recovery of vegetation. Bae et al. (2011) reported that moths feeding on trees increased continuously after forest fire.

Predator groups may be more vulnerable to disturbance than any other group because they are more abundant in stable environments (Choi et al. 2010). However, in the present study, the abundance of Formicidae and Araneae increased in response to disturbance, whereas Carabidae and Staphylidae did not change. In studies on feeding guilds of arthropods, Formicidae is usually grouped as a predator, but its food niches are diverse at the genus or species level (Hölldobler and Wilson 1990; Lobry de Bruyn 1999). Ponerinae ants are usually predators, whereas several species of developed Formicinae and Myrmicinae (e.g., *Lasius japonicus*, *Paratrechina flavipes*, and *Myrmica carinata* in present study) have herbivorous roles, using aphid honeydew or plant sap in addition to their main roles as predators. This may be one of the reason that the change of abundance of Formicidae is similar to that of herbivores. Although all arthropods in Araneae are predators, their habitats and predation strategies vary (Lee and Lee 1990; Uetz et al. 1999). Of the spiders (i.e. Araneae) collected in the present study, 81 % were ground foragers and 19% were web spinners. Web spinners decreased as intensity of disturbance increased, while ground-foraging spiders increased (Kwon unpublished). Abundance of ground-foraging spiders mainly determined the pattern of Araneae. Carabidae and Staphylinidae were associated with habitats provided by fire residuals (Gandhi et al. 2001). Most species of Carabidae and Staphylinidae have functional hind wings and, therefore, have strong dispersal ability. It is likely that these beetles from unburned forests may actively migrate to burned forests after fires (Kwon and Park 2005).

Various taxa and functional guilds respond differently to forest disturbances. Thus, it is more appropriate to use diverse arthropods rather than one taxa or one functional guild to understand the impact of disturbances on forests (Lawton et al. 1998; Buddle et al. 2006; Maleque et al. 2009). It is generally accepted that data obtained at fine taxonomic levels such as genus or species may have higher quality information than that of coarse levels such as order or family. Hence, a single taxon or group (i.e., butterflies, moths, carabid beetles, dung beetles, ants, spiders, syrphid flies, etc.) is more frequently used to assess effects of environmental change on ecosystems (Lee and Lee 1990; Kwon et al 2005; Masís and Marquis 2009; Kwon et al. 2010b; Lee and Ishii 2010; Bea et al. 2011). However, identification of arthropods at fine levels requires more time, money, and expertise. At coarse levels such as family, order or class, a variety of information from various fine levels would be pooled, resulting in the reduction of stochastic variation occurring at fine levels. In addition, the summation of information may lead to emergence of properties of the group that are not shown in each of its components. Coarse filter approaches to biodiversity monitoring may have some benefit for arthropods (Oliver and Beattie 1993). Identification of arthropods at coarse levels is easy, and errors during the identification may occur less than at fine levels. Hence, information obtained from coarse taxonomic levels may be more important than generally expected.

The different abundance changes among three functional guilds, detritivores, herbivores, and predators, show complexity in the response of arthropods due to environmental disturbance. This complexity may be theorized by simple arguments. If disturbance in forests is restrictively defined as tree kill, change of vegetation structure from various environmental disturbances such as fire, strong winds, clear-cutting, and pest damage may be similar in terms of disappearance of trees followed by growth of shrubs and herbs, and loss of litters (Choung et al. 2004; Walton et al. 2008; Kwon et al. 2010a; Peltola et al. 2010). In moderate disturbance, ground fire and thinning are similar in their patterns of selective tree kills. In this study, disturbance from fire and human activity acted additively on arthropod communities as evidenced by high correlation of DD and litter depth, and of litter depth and abundance of arthropods. Loss of litter caused by disturbance led to a decline of detritivores. However, death of trees led to growth of herbs and shrubs, resulting in increase of herbivores. In contrast, as predators have more flexible food niches than other feeding guilds, their changes are expected to be different from the simple pattern of herbivores or detritivores. When their favorite prey items decrease because of disturbance, they may alternatively feed on new increasing prey item. More diverse patterns were found among predators compared herbivores and detritivores. Diversification of arthropod communities in intermediate disturbance was found as well as other studies (Blair and Launer 1997; Wang and Chen 2010). Our results suggest that natural recovery of burned forest led to less impact to and more diversity of arthropod communities compared with reforestation of burned forests.

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Impacts of Forest Fires on Ecosystems Functioning including Biodiversity and Climate Change: a perspective from Hindu-Kush Himalayan (HKH) Region

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Abstract

Wildfires in high altitude Hindu Kush-Himalayas (HKH) ecosystems are a major driver for destruction of pristine biodiversity, including the habitats of many rare species. During the long and intense dry seasons occurring annually in the region, wildfires are a regular phenomenon, many of them having a potential to cause major damages; e.g., serious degradation of forests, changes of ecosystem properties, and deterioration of social and economic conditions in some land-use systems and natural vegetation types. Fires occurring in the highlands of Tibet, Sikkim, Bhutan and the northern part of Nepal at altitudes from 2,700 to 3,800m above sea level often cross national borders, especially during the dry winter fire season (November to January) (Schmidt-Vogt1989). Whereas, the fires are more common in lowlands in the Hindu Kush-Himalayan region during the hot dry and windy summer season (February to May) (also associated with agricultural burning). Observations indicate that the occurrence of wildfires is increasing as a consequence of regional warming and extended dry spells. The southern slopes of the mountains are primarily affected, since they are generally warmer and drier compared to northern slopes and are therefore exposed to high human pressure. “Atmospheric Brown Clouds” (ABC) are a ‘hot topic and burning issue’ among scientists, politicians and scholars in the region in recent years. ABC are consequences of socio-economic changes, an expression of escalating air pollution and a major driver of regional climate change. It’s net positive feedback

to the regional climate shape a vicious circle with increasing occurrence of wildfires in the region. This paper reviews the impacts of wildfires on ecosystems particularly to the biodiversity and regional climate.

INTRODUCTION

Wildfires in high altitude ecosystems of Hindu Kush-Himalayas (HKH) region in recent years have become a major driver for destruction of pristine biodiversity, including the habitats of many rare species. They are also affecting cultural heritage sites and land-use systems that provide the basis for livelihoods to a population of around 150 million people living in the mountain region. Most importantly, the secondary consequences of wildfires include the destruction of soil protecting vegetation cover, affecting water regimes for a population of 1.4 billion (UNEP 2007). These fires are often border crossing in nature and initiated political discourse in transboundary smoke haze pollution.

Fires occurring in the highlands of Tibet, Sikkim, Bhutan and the northern part of Nepal at altitudes from 2,700 to 3,800m above sea level often cross national borders, especially during the dry winter fire season (November to January). Observations indicate that the occurrence of wildfires is increasing as a consequence of regional warming and extended dry spells. The southern slopes of the mountains are primarily affected, since they are generally warmer and drier compared to northern slopes and are therefore exposed to high human pressure. The wildfires in the recent past in the southern stretch of the HKH region not only contributing to regional and the overall global problem but also pose a higher risk to the communities if looked at from the point of view of the fragile Himalayan ecology (SAARC 2009).

At the same time, the “Atmospheric Brown Cloud” (ABC) has come into discourse among scientists, researchers, politicians and academia after a preliminary assessment report published by UNEP in 2002 (http://www.unep.org). Now, it is a ‘hot topic and burning issues’ particularly in south Asia regarding regional climate change and in impacts on air quality, agricultural production, human health, changing glacier dynamics and wildfire regimes (Ramanathan et al. 2008, Thompson 2006, Gustafsson et al. 2009). Despite there is a general consensus on one of the regional climate driver, ABC, the source of it is still under debate (Ramanathan et al. 2008, Thompson 2006, Gustafsson et al. 2009, Economic Times 2008).

Transboundary wildfires and haze pollution is an emerging issue in south Asia. Moreover, fire is the most important disturbance agent in global vegetation cover worldwide, affecting between 3 and 4 million square kilometers annually

(GFMC 2009). While there is clear evidence of the historic role and timescale of fire in many ecosystems, along which many fire-dependent ecosystems evolved, the current trend provides evidence of increasing use of fire in land use and land-use change as well as an increase of destructive wildfires (uncontrolled and unwanted fires). Burning of forests and other vegetation is a major driver of transferring carbon from the terrestrial sphere to the atmosphere. It constitutes a significant source of radiatively active (greenhouse) gases and aerosols. Fires globally consume about 5% of net annual terrestrial primary production per annum, and release about 2-4 billion metric tons of carbon (C) per year. Approximately 0.6 billion tons of carbon emitted to the atmosphere come from tropical deforestation and peat fires, the global figure is equivalent to about 20-30% of global emissions from fossil fuels (GFMC 2009).

A recent study (by the National Center for Ecological Analysis and Synthesis, California) reveals that the emissions of carbon dioxide, a greenhouse gas adding to global warming, are about equal to half the output from burning fossil fuels such as coal, Balch and colleagues wrote in a study published 23 April 2009 in the journal Science on the role of fire in the climate system.

Further, one of the key messages of the UNEP report (UNEP 2007) is that the Earth's surface is warming. This is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level. Other major impacts include changes in water availability, land degradation, food security, and loss of biodiversity. The Conference of the Parties to the UNFCCC has identified 'fire management' as one of the options for reducing emissions from deforestation and forest degradation in developing countries (REDD concept) as fire is one of the defined 44 "Essential Climate Variables" (ECVs).

While in the past century the global average temperature increased by 0.74°C, the best estimate of the Intergovernmental Panel on Climate Change (IPCC) for additional warming over the current century is projected to be from 1.8 to 4.0°C. Climate change may further exacerbate the loss of biodiversity and degradation of land, soil, forest, freshwater and oceans. The projected increase in frequency and intensity of heat waves, storms, floods and droughts would dramatically affect many millions of people including those living in Hindu-Kush Himalayan region.

INCREASING TREND OF WILDFIRE INCIDENTS

During the long and intense dry seasons occurring annually in the region, wildfires are a regular phenomenon, many of them having a potential to cause major damages; e.g., serious degradation of forests, changes of ecosystem properties, and deterioration of social and economic conditions in some land-use systems and natural vegetation types. The ecosystems and society are very vulnerable to wildfires, in general, and to the secondary disasters, such as landslides and flash floods, that follow disastrous wildfires.

A Case Study: Nepal

Active fire incidents and total burning days are increasing in Nepal from the recent past (Figure 1) impacting huge loss of lives, properties and natural resources. Forest fire is considered one of the climate induced disasters in the National Adaptation Programs of Action (Nepal NAPA 2010). In 2009 alone forest fires claimed 49 lives injured 9 people; about 146,742 hectare of forest destroyed and caused the loss of about Rs 134,415,000 (GFMC 2010, MoFSC, 2009, RSAWFN 2009). A total of 9 people were reported dead, 3 people seriously injured, 431 houses were completely destroyed, 92 animals killed and more than 82,000 hectares forests were burnt in 2010 fire season (RSAWFN 2009). A proper damage assessment of a fire is not being practice in Nepal. Moreover, there is no any record of impacts of fire on wildlife, medicinal plants, secondary disasters (health and water induced disasters) and, regional climate (atmospheric brown cloud).

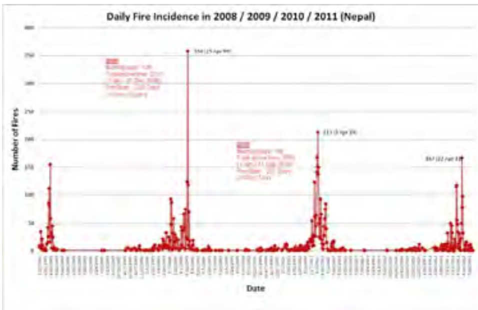

Figure 1: Daily fire incidence in Nepal from 27 March 2008 to 21 May 2011.
(From 2009 to 2010 Burning days increased by 22% and Active fires increased by 30%, Peak fire generally occurring in last week of April)
Data source: FIRMS-MODIS/FAO/UMD/NASA.

On 12 March 2009, the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Aqua satellite caught a glimpse of a relatively rare event: large–scale forest fires in the Himalaya Mountains of Nepal (Image 1). Places where the sensor detected active fires are outlined in red. The image is centered on Nepal and shows the towering Himalaya Mountains arcing through the small country. Many national parks and conservation areas are located along the northern border of the country, and the fires appear to be burning in or very near some of them.

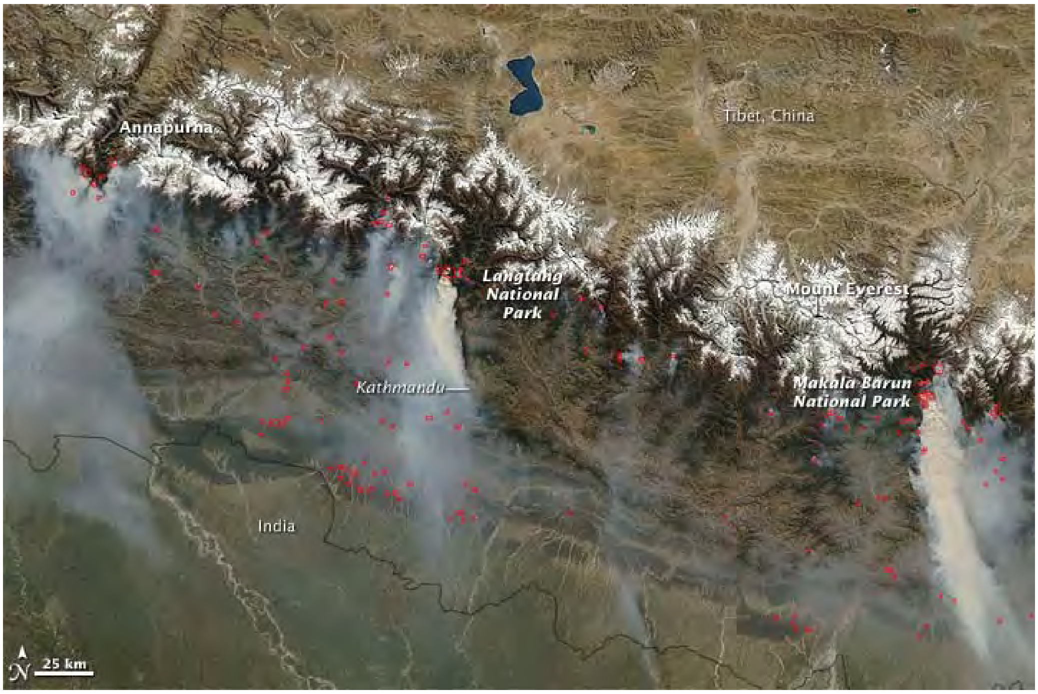

Image 1: Huge plumes of smokes coming from mega-fires in Makalu-Barun National Park, Langtang National Park and Annapurna Conservation Area of Nepal which cross the India border. Source: Earth Observatory, 12 March 2009.

South Asia Regional Fatality Record

In south Asia 109 people died and injured in wildland fires, notably in Nepal (58) and India (51) in 2009 (http://www.fire.uni-freiburg.de/GFMCnew/2010/GFMC-Bulletin-01-2010.pdf). Annual Regional Wildland Fire Fatalities Report covering the year 2009 is based on the evaluation of media (newspaper, radio broadcasts and TV) published on the internet, as well as agency reports (Note: This report includes all death and injuries of firefighters and civilians related one way or the other to wildfires, i.e. accidents during firefighting, accidents on the way to respond to a fire, wildfires affecting people in wildlands or structures ignited by wildfires, or other indirect accidents, e.g., by smoke-reduced visibility, or people admitted to hospitals, medical treatment or deceased due to wildland fire smoke inhalation. Since only a fraction of wildfire-related accidents may be reported through media and subsequently published on the web (http://www.fire.uni-freiburg.de/media/news.htm) and data stored by the UNISDR-Regional South Asia Wildland Fire Network, it has been presume that the attempt to compile a regional statistical database is still very incomplete and may scratch the surface only.

The global report reveals that 374 deadly wildland fire fatalities and 160 injuries were reported worldwide in 2009.

Risk to downstream population from secondary disasters

Observation indicates a major portion of the forest areas in the mountains of the HKH region burnt annually. Already large areas of the Himalayan forests have cleared indiscriminately for agriculture making them vulnerable to soil erosion and landslide. Large amount of sediment production in upstream areas that is transported through rivers causing river bed rise and consequently resulting in flooding in the downstream of the HKH.

An estimate from Nepal in 2009 fires revealed that about 40 percent forest cover has been lost in upstream areas from the wildfires. The situation might create a risk of soil erosion, mud-flow, debris flow and flooding in the downstream areas imposing a high risk to people leaving in downstream areas during the rainy seasons. Damage assessment, rehabilitation works and warning system development are the urgent needs.

WILDLAND FIRES AND BIODIVERSITY CONSERVATION

Forest fire was once viewed as synonymous with forest destruction and degradation (Botkin 1990). Certain forms of disturbance, however, are now held by ecologists and conservation biologists to play a fundamental and creative role in maintaining the natural heterogeneity in environmental conditions that organisms experience through space, time, or both. The importance of disturbance to the ecology of species and conservation of biodiversity has gained widespread recognition (Brawn et al. 2001, cited by Connell 1978, Sousa 1984, Pickett & White 1985, Petraitis et al. 1989, DeGraaf & Miller 1996a, Askins 2000). In restoration ecology, landscape ecology, and the concept of ecosystem management, natural disturbance is now generally recognized as essential for maintaining biodiversity (Brawn et al. 2001, cited by Alverson et al. 1994, Askins 2000).

Some of the models that related disturbance to enhanced species diversity are:

- density-independent mortality of organisms
- changes in habitat and resource levels
- natural disturbance on species diversity at the landscape or regional scale (spatially structured populations)

Conservation strategies involving the management of disturbance through some combination of flooding, application of fire, or the expression of wildfire, and use of certain types of silviculture have the potential to maintaining biodiversity at the local, landscape, and regional scale (Brawn et al. 2001).

However, uncontrolled wildland fires have a greater degree of threat to biological diversity at ecosystem level (NBS 2002) but it can be improved and/or maintained when controlled burns are applied as fires vary more in terms of type and intensity resulting in highly variable fire effects (Trollope et al. 2008).

Society tends to have various competing goals, many of which depend on biodiversity. When humans modify an ecosystem to improve a service it provides, this generally also results in changes to other ecosystem services. As a result of such trade-offs, many services have been degraded. The Millennium Ecosystem Assessment shows that human actions often lead to irreversible losses in terms of diversity of life on Earth and these losses have been more rapid in the past 50 years than ever before in human history (Green Facts).

Biodiversity loss, due to unwise use of fire, has direct or indirect negative effects on several aspects of human well-being at local and national level, such as food security, vulnerability to natural disasters, energy security, and access to clean water and raw materials. It also affects human health, social relations, and freedom of choice.

Impacts of disturbances in floral and faunal diversity

The hypothesized ultimate agent of decline acting on a population is the unsuitable fire management programme implemented within the protected areas (Pfab and Witkowski 1999). Many aspects of the disturbance ecology of birds require further research. Important questions involve associations between the intensity and frequency of disturbance and the viability of bird populations, the scale of disturbance with respect to the spatial structure of populations, and the role of natural vs. anthropogenic disturbance (Brawn et al. 2001). Reilly et Al. (2006) observed that there was no significant effects of burning on total bird abundance or species richness in savanna. Patchy fires have been an important natural disturbance in tropical ecosystems for millennia (Reilly et Al. 2006).

Fire is an important component in the maintenance of grassland diversity (Uys et al. 2004, cited by Freeman 1998, Lunt and Morgan 2002). It has long been used to manage grasslands for livestock production in many part of the world. Though the dominant grasses were strongly influenced by season and frequency of fire, forb diversity showed no consistent trends. Most forb species tolerate a wider range of season and frequency of fires than the dominant grasses. However, to accommodate those species with low tolerance of frequent fires, parts of the landscape will require less frequent fires (Uys et al. 2004).

Understanding and applying ecological disturbance offers opportunities to conserve large and diverse group species—many of which are declining as a result of habitat loss and successional changes in habitat structure (Brawn et al. 2001).

Uncontrolled forest fires have devastating effects on animals with limited mobility. But, Kiss and Magnin (2006) found that Mediterranean land snail communities are particularly resilient to fires. Although abundance is drastically reduced after fire, species richness and diversity of communities are preserved, whatever the fire regime, since the time lapse between two successive fires is longer than the time required for malacofauna recovery (i.e. around 5 years).

Further, a study on bird species by Slik and Balen (2006) found that three years after fire the number of birds and bird species were similar for undisturbed and burned forests, but species diversity and turnover were significantly lower in the burned forests These differences are probably related to the fact that undisturbed forests provide more spatial variation in vegetation structure (niche space) than burned forests. The shift in bird species composition between undisturbed and burned forests was significantly related to changes in the forest understorey (appearance of pioneer herbs and woody plants after fire) and the middle- and upper storey (strong decrease in foliage cover after fire). The species composition in tropical forests is strongly related to (vertical) vegetation structure and plant species composition. When fires become too frequent for the vegetation to recover, both the flora and avifauna are likely to become seriously negatively affected to the point that recovery becomes impossible (Slik and Balen 2006).

Theory suggests that species richness should be highest at intermediate levels of disturbance (Connell 1978, Huston 1979). However, this is not always the case. In the Scottish Highlands, plant diversity was found to increase with fire frequency (Hobbs et al. 1984) while, conversely, in the North American prairies, plant diversity decreased with increasing fire frequency (Uys et al. 2004, cited by Collins et al. 1995). Therefore, researchers should always be careful while applying disturbances in biodiversity conservation considering species-habitat interaction in particular geographical location.

Fire and ecosystem diversity

Under natural conditions, fire is the major driver that governs the development and function of most deciduous, coniferous, and mixed forest types at temperate latitudes (Brawn et al. 2001, cited by Wright and Bailey 1982, Attiwill 1994, Frost 1998). Fire, along with other factors, is key in maintaining entire ecosystems such as grasslands and savannas at temperate and tropical latitudes, and Mediterranean-type shrublands (Brawn et al. 2001, cited by Moreno and Oechel 1994, McPherson 1997).

Reductions in plant diversity and the strong dominance of the forest understorey by only a few species of pioneer herbs, shrubs and trees (Slik and Eichhorn 2003) also strongly reduce habitat heterogeneity in burned forests. (Slik and Balen 2006).

Many studies (Brawn et al. 2001, Connell 1978, Sousa 1984, Pickett and White 1985, Petraitis et al. 1989, DeGraaf and Miller 1996a, Askins 2000, Wright and Bailey 1982, Attiwill 1994, Frost 1998, Moreno and Oechel 1994, McPherson 1997, Marynowski and Jacobson 1999.) revealed that the frequency and intensity of wildland fire is a determinant of the presence of many terrestrial habitat types (or ecosystems) (Figure 2) in many part of the world that support significant components of species and ecosystem diversity.

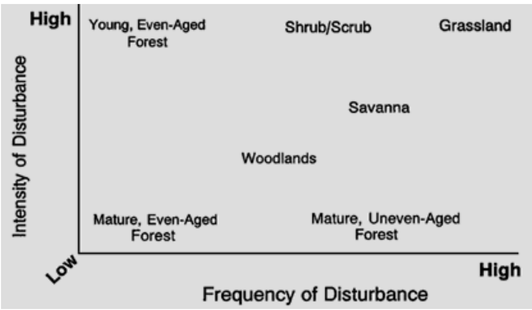

Figure 2 (Left). Some terrestrial habitats quali ordinate according to frequency and intens disturbance. Even-aged forest can result from fir throw, floods, or even-aged silviculture. Uneve forest results from small-scale wind throw or u aged silviculture. Woodlands and savanna resul moderate to light intensity frequent fires. Gra generally result from frequent and intense fire, g or both (Adopted from Brawn et al. 2001)

Despite the importance of fire in shaping many forest ecosystems, most fire studies have focused on the effects of fire on vegetation; relatively less attention has been paid to the effects of fire on genetic and faunal diversity (Reilly et.al. 2006, cited by Parr and Chown 2003).

Fire and alien species

The most significant effects of alien grasses on ecosystems result from interactions between grass invasion and fire. Alteration of fire regimes clearly represents an ecosystem-level change caused by invasion (D’Antonio et. al. 1992). The effects of alien grasses on ecosystem function (fire, nutrient loss, altered local microclimate, prevention of succession) are significant on the local scale and are becoming increasingly important on regional and global scales. Moreover, the interaction of competition with alien grasses, fire, and the prevention of succession now represents a substantial global threat to biological diversity on the genetic, population, and species levels (D’Antonio et al. 1992).

Management of fire is destined to become an increasingly significant challenge due to increased fuel loads arising from the invasion of exotic grasses, either on the rainforest boundary or within patches where the canopy has been opened by fire (Liddle et al. 2006).

The regional population is at risk by more frequent and more intense fire due to the invasion of exotic grass species and land use changes in the catchment which result hydrologic changes lead to increased drying of the rainforest habitat (Liddle et al. 2006). Similar situation has already been observed in Chitawan National Park of Nepal.

Fire and nutrient cycling

Fires themselves alter nutrient budgets profoundly; they volatilize some elements (notably carbon and nitrogen) while converting others into biologically more available, mobile forms for at least a short time. The selective loss of nitrogen in particular drives ecosystems toward nitrogen limitation. Nutrient losses to stream-water, ground-water, and the atmosphere are also enhanced following fire, and these can have significant effects on the chemistry of the atmosphere regionally and globally (D’Antonio et al. 1992).

Socio-economics of pyrodiversity

Archaeology provides a long-term perspective on human actions and their environmental consequences that can contribute to conservation and restoration efforts (Hayashida 2005). In one hand, ecologists have increasingly turned to ‘sociology of environment’ to explain and manage modern ecosystems and landscapes. And the other hand, archaeologists become more involved in research directed at contemporary environmental issues. But, they need to consider the potential uses and abuses of their findings in management and policy debates (Hayashida 2005).

The use of prescribed burning is a much debated issue in ecology and forest management, particularly in areas prone to major wildfires that threaten people, property, and forests. In the United States, the likelihood of catastrophic fires increased with the practice of fire suppression that interrupted the natural and cultural fire regimes of the past and resulted in large fuel accumulations (Hayashida 2005).

In the southern Appalachian mountains, frequent burning was used by native Americans to improve conditions for travel and game, and later by European settlers to improve grazing for livestock (Cathryn et al. 2006, cited by

Brose et al. 2001). In Nepal major cause of fire is link with livelihood of people (e.g. to boost-up new flush of grass for livestock, to facilitate collection of non-timber forest products, hunting wild animals, etc.) (Sharma 1996).

A study conducted in in Senegambia (Stoate et al. 2001) reveals that more sustainable use of savanna farmland could have both agronomic and wider conservation benefits, and the provision of information that accommodates farmers' cultural and economic incentives could benefit both farmers and wildlife. Farmers in this study reported a continuing decline in the area of trees, shrubs and fallow land in the subsequent 30 years, suggesting an increase in the area of open land lacking shrubs and trees and representing unsuitable habitat for Whitethroats.

Vaux et al. (1984) conducted the first study on the influence of fire on the economic value of forest recreation. The authors state, ''Willingness-to-pay is an appropriate measure for valuing the effects of fire on forest recreation''. Using a random effects probit model (Loomis and Caban 1998) to account for the panel nature of the data, the average willingness to pay to reduce catastrophic fire on 2570 acres was $56 per household. Since acreage of habitat protected is a statistically significant variable in the willingness-to-pay function, this function can be used by managers to evaluate the incremental benefits of different fire management plans that reduce additional acres burned. These benefits can serve as justification for funding of prescribed fire and fuel reduction programs to protect critical habitat of an endangered species (e.g. Northern and California Spotted Owl).

There is growing recognition that protection of other environmental values beyond traditional multiple uses needs to be incorporated into fire decision making (González-Cabán and Chase 1992, González-Cabán 1993). These values often reflect public desire to know that rare and distinctive ecosystems exist (e.g. existence value, proposed by Krutilla (1967) and will be protected for future generations (bequest value) as well as being available for visits at future times (option value). Along with recreation, these three values are sometimes referred to as Total Economic Value (Randall and Stoll 1983). These values may be particularly important for preservation of old growth forests for threatened species (Loomis and Caban 1998).

Management options for biodiversity conservation

Buildup of forest fuels such as thick shrub cover or woody debris contributes to the potential for wildfire in many ecosystems. Recreating natural fire regimes and actively managing fuels have often been advocated to maintain biological diversity and reduce the risk of catastrophic wildfire in forests (Wales et al. 2006, Hann Allen et al. 2002, Marston et al. 2001, Stuart 1998). Thinning and prescribed fire are being used extensively across the interior western United States to reduce the risk of large, severe wildfires. However, the full ecological consequences of implementing these management practices on the landscape have not been completely evaluated. (Wales et al. 2006). Prescribed fire as a means of restoring or maintaining biodiversity is becoming common place throughout North America and elsewhere (Askins 2000), but long-term studies of periodic fire and particular species are few (Brawn et al. 2001). Therefore, researchers/land managers need to know how different fuel reduction practices affect wild animal (e.g. small mammal) populations to better integrate wildlife management with forest management (Cathryn et al. 2006).

Now, there is a common understanding that fire suppression, timber harvest/thinning, and ungulate grazing have reduced wildfire frequency, increased conifer establishment or shrubby vegetation, and changed the overall pattern and structure of forests (Wales et al. 2006, Hann et al. 1997, Hessburg et al. 2000).

A study (Barbero et al. 1987) reveals that when frequent fires occur with fire interval of under 10 years, vegetation structure tends to be very simple, with only low shrubs and grass, and fire regime may also induce change in fauna biodiversity (Kiss and Magnin 2006, Gill and McCarthy 1998).

However, very less studies have been done so far in impacts of wildland fires on biodiversity at genetic, species and ecosystem levels in south Asian region. Our current understanding of plant and animal community responses to tropical forest fires is limited and strongly geographically biased towards South Asia.

TRANSBOUNDARY FIRES, HAZE POLLUTION AND REGIONAL CLIMATE

Atmospheric Brown Cloud (ABC): implications to regional climate change, glacier dynamics, human health, food security and wildfire regimes

The Atmospheric Brown Cloud Project Report of UNEP released in November 2008 is the latest and most detailed regional assessment of the phenomenon.

Wildland fires, the burning of agricultural wastes, fossil fuels in vehicles, industries and power stations and emissions from burning wood stoves, cow dung and other ‘bio fuels’ form the haze - a mass of ash, acids, aerosols and other particles, where black carbon could now be responsible for between 10 to 40 per cent of current climate change (Ramanathan et al. 2008, Thompson 2006, Gustafsson et al. 2009).

The brown cloud in the atmosphere consists of pollutant particles (primary aerosols) and gases such as nitrogen oxides (NOx), carbon monoxide (CO), sulphur dioxide (SO2), ammonia (NH3), and many organic gases and acids. The brown cloud plumes are formed by the result of the combustion of biofuels in houses and industries, biomass burning, and fossil fuels in densely populated region (Ramanathan et al. 2008). Some major cities in Asia may be up to 25 per cent dimmer or darker than they were half a century ago. Reductions in visible light may also be harming agriculture, again with implications for poverty and for combating hunger under the Millennium Development Goals (MDGs).

Emissions of black carbon may also be accelerating melting rates of glaciers in mountain ranges such as the Himalayas, with the dark particles absorbing sunlight and raising ice temperatures. In addition, black carbon – a key component of brown clouds in some parts of the world – is contributing to dimming and reducing the amount of sunlight hitting the ground in polluted parts of the globe (Ramanathan et al. 2008, Gustafsson et al. 2009).

The implications of the ABC has been becoming a hot topic among scientists, politicians and scholars in the region in recent years. The atmospheric concentrations of brown clouds are large mainly during the summer season since precipitation removes the aerosols efficiently during other seasons. Satellite data have revealed that ABC plumes, measuring 1 - 3 km thick, surround the Hindu Kush-Himalayan region during November to March (Ramanathan et al., 2008).

Wildfires in the countries in the region are contributing to a tick blanket of smoke (Brown Cloud) hanging over the south of Hindu-Kush Himalaya (mainly south of Nepal covering major cities e.g. Butawal, Birgunj, Jankpur, Biratnagar etc. and Uttaranchal and Himanchal Pradesh in India) on 25 April 2009 (compare Image 2 with Image 3).

The brown cloud is blocked by the Himalaya range (Image 3 and Image 6) and confined in the south of it. These so called brown clouds have a major impact on air quality (Image 4), human health (lung, heart, skin and eye diseases), regional climate, and natural resources.

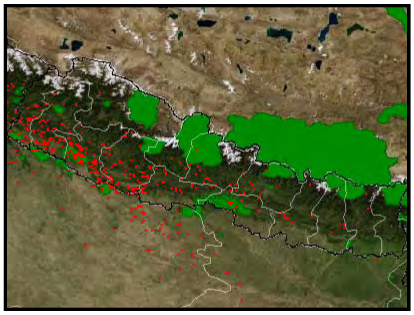

Image 2: 420 fires were detected in past 24 hours in Nepal. (Source: FIRMS-MODIS/UMD/NASA, Date: 25 April 2009, 08:58:23 UTC)

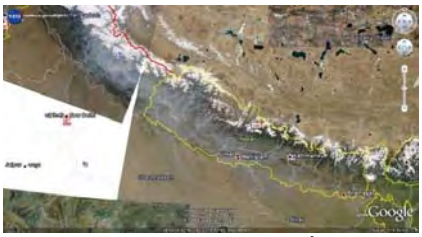

Image 3: Haze primarily coming from vegetation fires in the high altitude Himalayan region. The smokes is blocked by the range of Himalaya and confined to the south of the range. (Source: MODIS Rapid Response System (opened with KMZ file for Google Earth), 25 April 2009).

Transboundary wildfires and haze pollution which are one of the component of ABC and poorly researched, are an emerging issue in south Asia which needs to be addressed collectively.

The cloud is considered mainly due to the vegetation fires, urban and industrial pollutions, agricultural burning, and bush clearing. This cloud is similar to the Atmospheric Brown Cloud (UNEP 2007) but appeared also in this summer which needs further validation.

Image 4: Faded Sun in the Morning. Photo taken from the Thapathali Bridge, Kathmandu at 07:15, 29 April 2009.

The 'brown cloud' along the Himalaya hover over northern India, Pakistan and Nepal during the beginning of winter season (Image 5) forming a thick blanket. It is considered that the wildfires or agricultural fires in the region contribute to it, though they are not solely responsible. The haze generally blown from the west probably results from a combination of smoke, urban pollution and dust from neighboring Pakistan might play a role. The images (Left) clearly shows that this haze, which is border crossing in nature, mainly originated from Pakistan and India forming a thick cloud of haze along the border between Pakistan, India and Nepal.

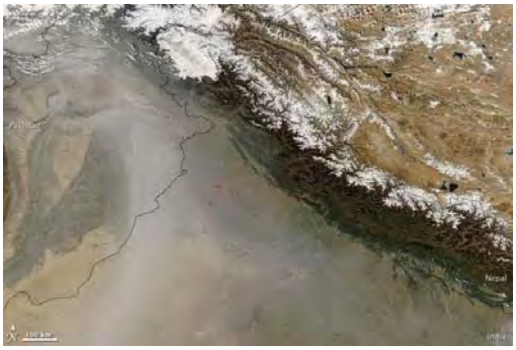

Image 5: MODIS on NASA's Aqua satellite image, acquired 16 November 2008. Thick smoke hides most of the areas of northern India (Amritsar, New Delhi, Jaipur), east Pakistan (Islamabad, Rawalpindi, Lahore, Okara) and south-west Nepal (Mahendranagar). (source: (NASA's Earth Observatory) http://earthobservatory.nasa.gov

Wildfires in the region contributed to a thick blanket of smoke hanging over the south of Hindu-Kush Himalayan covering major cities of Nepal (Viz. Dhangadi, Bhairahawa, Nepalganj, Pokhara, Kathmandu, Biratnagar etc.), the north and eastern region of India (Viz. Sitapur, Gorakhpur, Patana, Bhagalpur, Kolkota etc.) and most of the western part of Bangladesh on 16 March 2009, when the MODIS on NASA's Terra satellite passed over head and captured this image (Image 6).

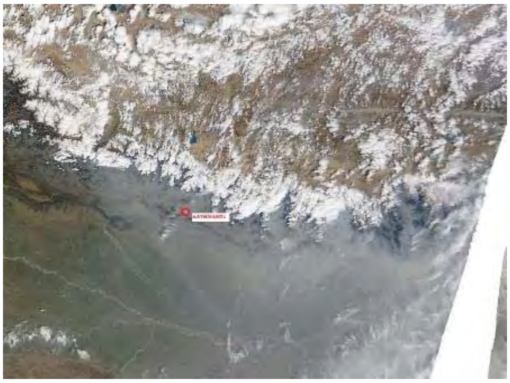

Image 6: Smoke haze over South Asia (source: Earth Observatory, 16 March 2009).

Professor Lonnie Thompson of Ohio State University and a team of researchers found (2006) that high-altitude glaciers, despite residing in colder temperatures, are more sensitive to climate change. As more heat is trapped in the atmosphere, he said, it holds more water vapour. And when the water vapour rises to high altitudes it condenses, releasing the heat into the upper atmosphere, where high mountain landscapes feel the brunt of warming. He further stated that water the Himalayas have is dwindling fast. The glaciers in the Himalayas collect water from the monsoon in the wet season, and release it in the dry season. But how effective they are depends on how much water is in the glaciers (ENN 2008).

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It has been warned that if the current rate of retreat continues unabated, these glaciers and snow packs are expected to shrink by as much as 75 percent before the year 2050 (Ramanathan et al. 2008).

Atmospheric Brown Cloud (ABC) Radiative Forcing

The absorption of solar radiation by the surface and the atmosphere is the fundamental driver for the physical climate system, the biogeochemical cycles, and for all life on the planet. ABCs have significantly altered this radiative forcing over Asia. Brown clouds cause dimming (by at least 6 per cent in south Asia compared with the pre-industrial values) at the surface and soot in it increase solar heating of the atmosphere (absorbed solar radiation at the surface by +15 Watt per square meter compared with the pre-industrial values) (Ramanathan et al. 2008).

Between 1950 and 2002, soot emissions increased three-fold, while sulphur emissions have increased seven-fold in India. Black carbon (BC) in the brown cloud has increased the vertically averaged annual mean solar absorption in the troposphere (from the surface up to 14 km in altitude) by about 15 per cent (about 14 W m^{-2}) and the solar heating at elevated levels (1 - 4 km) over India by as much as 20 - 50 per cent (6 - 20 W m^{-2}) (Ramanathan et al. 2008). BC is formed through the incomplete combustion of fossil fuels, biofuel, and biomass, and is emitted in both anthropogenic and naturally occurring soot. It warms the Earth by absorbing heat in the atmosphere and by reducing albedo, the ability to reflect sunlight, when deposited on snow and ice. Black carbon stays in the atmosphere for only several days to weeks, whereas CO2 has an atmospheric lifetime of more than 100 years. Black carbon is a potent climate forcing agent, estimated to be the second largest contributor to global warming after carbon dioxide (CO2) (Ramanathan and Carmichael 2008).

Not only vehicles and industries are the sources of air pollution and greenhouses gases but also fires contribute to them. Due to the haze, the amount of sunlight falling on the ground has decreased by six per cent in India (UNEP 2007) and that has a direct bearing on the plant growth. In the region, during the dry season, thousands of fires burn each year as people clear cropland and pasture in anticipation of the upcoming wet (growing) season. Intentional fires also escape people's control and burn into adjacent forest. The smoke from these fires crosses border affecting climate far away.

A discourse among politicians and the scientist are going on the topic of the regional climate change. A United Nations Environment Programme (UNEP) study has warned that Asian cities from New Delhi to Beijing are getting darker, glaciers on the Himalayas are melting faster and weather system is getting more extreme because of high pollution levels (UNEP 2007). However, Sibal (Science and Technology Minister of India) argued that the Asian countries are not responsible for 'brown cloud' formation contending that the per capita emissions of India are 1.2 tonnes as against 23 tonnes in the US and 10 tonnes in European countries (The Economic Times 2008). But scientists say the effects of climate change are only getting worse.

Climate change and global warming are significant challenges that the world, particularly the developing and least developed countries, face this century. Nado Rinchhen, Deputy Minister, Royal Government of Bhutan argued that 'although Least Developed Countries (LDCs) like Bhutan contribute the least to global warming, they will nonetheless be seriously affected by the impacts of climate change'. It is important to realize that climate change is not just an environmental problem but a serious challenge to sustainable development and the livelihood of the Bhutanese people' (Bhutan NAPA 2007).

Hindu-Kush Himalayan region is critically vulnerableto poor people in rural and remote areas tend to be the most directly affected by the decline of biodiversity and deterioration or loss of ecosystem services due to the climate change (UNEP 2007).

Brown cloud is primarily responsible for total cooling effect by 40%. Summer fires could contribute significantly to the melting of glaciers and outburst of the glacier lakes (GLOF) (UNEP 2007).

Impact of brown cloud on monsoonal climate, glaciations and socio-economy over south Asia

The South Asian region is characterized by diverse ecosystems and socio-economic and cultural settings resulting from a wide range of land-use systems and climatic conditions. Consequently these ecosystems have diverse fire regimes and vulnerabilities.

These so called brown clouds have a major impact on air quality, human health (lung, heart and eye diseases), regional climate, and natural resources. Due to this haze many domestic flights in Nepal have been cancelled and some international air flights have been delayed in Nepal these days.

Brown cloud-induced dimming is considered as the major causal factor for the change of monsoonal rainfall pattern (intensity, duration and frequency). For instance, rainfall over the northern half of India has decreased. The number of rainy days for all India is also decreasing, although the frequency of intense rainfall is increasing, leading to more frequent floods in downstream and soil erosions, landslides and debris-flows in upstream areas. The densely populated areas in the region are highly vulnerable from water-induced disasters. Rainfall over the Indo-Gangetic Plain has decreased by about 20 per cent since the 1980s

(Ramanathan et al. 2008).

According to the UNEP report, the toxic material could kill 340,000 people in China and India every year. The toxic clouds also threaten the massive Hindu Kush-Himalaya-Tibetan glaciers.

CONCLUSIONS AND RECOMMENDATIONS

Wildfires in high altitude Hindu Kush-Himalayas (HKH) ecosystems are a major driver for destruction of pristine biodiversity, including the habitats of many rare species. However, specific study on impacts of wildfires at genetic, species and ecosystem levels in HKH region is poorly understood.

Occurrences and extents of wildfires in the countries in South Asia are increasingly impacting socio-economy and environment and are contributing to regional and global climate change. Fires affecting sensitive mountain ecosystems have considerable consequences on secondary disasters such as landslides, mudslides, erosion, increased water runoff, and flash floods.

It has been recognized that the involvement of local communities, which are suffering most by the consequences of inappropriate burning practices and wildfires, is crucial to reduce the adverse impacts of fire. But, a lack of fire research and management capability exists in the region, including monitoring, early warning, early detection and ecological and socioeconomic impact assessment.

Therefore, wildland fire management involving local communities (CBFiM approach) at Forest User's Group level could be a best strategy to:

- increase resilience of community to wildfire disaster and its secondary consequences like secondary disasters (soil erosion, landslides, flooding, regional climate change due to the Atmospheric Brown Cloud, etc.)
- establish linkages of ecosystem services with wildland fires management
- link wildfire risk reduction with sustainable livelihoods and development

With much of the high altitude Himalayan region currently in the grip of a long and intense dry seasons occurring annually, the role of under-lying moisture deficits in the fluctuating nature of south Asia's experience with wildfire is notable, many of them having a potential to cause major damages; e.g., serious degradation of forests, changes of ecosystem properties, and deterioration of social and economic conditions in some land-use systems and natural vegetation types. Equally perhaps, international scientific study has confirmed that significant climate change is under way.

Atmospheric Brown Clouds (ABC) could be the major driver to the regional climate change and pollution though not well understood (Ramanathan et al. 2008, Gustafsson et al. 2009). Consequently, rainfall over the Indo-Gangetic plain has decreased by about 20 per cent since the 1980s negatively affecting to the agricultural production, changing glacier dynamics and wildfire regimes (GFMC 2009, Gustafsson et al. 2009, Ramanathan et al. 2008,). Climate change threats mainly to the largely agrarian population that still depends on subsistence agriculture for their daily livelihood in the region.

It's net positive feedback to the regional climate shape a vicious circle with increasing occurrence of wildfires in the region. Observations indicate that the occurrence of wildfires is increasing as a consequence of regional warming and extended dry spells.

Besides the role of climate extremes (droughts) as an aggravating condition for destructive fires, the majority of fires that are resulting in degradation of forests and other vegetation, are caused by human activities in the rural area. Since local communities will benefit first from reduced occurrence and severity of fires participatory approaches in fire management (community-based fire management) are imperative.

Vegetation destruction by fire is a cross-sectoral issue and disaster risk affecting human health, security and livelihood in many countries the region, and contribute to destabilization of land cover and to climate change, policies addressing the pressing fire problems are needed at national to international levels.

Therefore, it has been recommended:

- to enhance regional cooperation and collaboration in wildland fire research and development, particularly, among SAARC, ICIMOD and UNISDR-Regional Wildland Fire Network.
- to conduct further assessments of atmospheric brown cloud (ABC) including haze from wildland fires, as well as options for action
- to enhance and strengthen bilateral/multilateral and international cooperation in wildland fire management for creating synergies and sharing knowledge and technical and human resources among countries in the region by accepting and promoting principles, norms, rules, and decision making procedures within a guiding framework that individual countries agree on;
- to strengthen local communities coping with wildfires and aiding them in addressing the consequences of climate change and wildfires and the effects on their livelihoods;
- to assist countries in fire management planning, research and development,

enhancing institutional and technological capabilities and developing synergies through coordinated and collective action both within the region and internationally;

- to emphasize the improvement of participatory/community-based fire management approaches and institutional and technological capabilities at all levels; and
- to promote education and awareness-raising programmes on wildfire prevention.

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- Asian Brown Cloud (ABC) over Hindu-Kush Himalaya region: http://www.fire.uni-freiburg.de/GFMCnew/2009/03/0319/20090319_ne.htm
- Biomass-burning 'behind Asian brown clouds': http://www.fire.uni-freiburg.de/media/2009/01/news_20090127_in.htm
- Brown Clouds over South Asia: Biomass or Fossil Fuel Combustion?: http://www.fire.uni-freiburg.de/media/2009/01/news_20090127_in2.htm
- Climate change 'fan Nepal's fires': http://www.fire.uni-freiburg.de/media/2009/04/news_20090403_ne.htm
- Fires in Nepal: http://www.fire.uni-freiburg.de/GFMCnew/2009/03/0323/20090323_np.htm
- Fires in Nepal: http://www.fire.uni-freiburg.de/GFMCnew/2009/04/0424/20090424_np.htm
- Fires in Nepal: http://www.fire.uni-freiburg.de/GFMCnew/2009/04/0427/20090427_np.htm
- Forest fire a major problem: http://www.fire.uni-freiburg.de/media/2009/04/news_20090428_in.htm
- Planting Trees and Managing Soils to Sequester Carbon: http://www.fire.uni-freiburg.de/media/2009/01/news_20090106_glo.htm
- Third-World Stove Soot Is Target in Climate Fight: http://www.fire.uni-freiburg.de/media/2009/04/news_20090420_in.htm
- UN agency urges measures to slash non-carbon dioxide greenhouse gas pollutants: http://www.un.org/apps/news/story.asp?NewsID=31952&Cr=unep&Cr1=
- UN-backed 'clean stove' initiative to save lives and heal environment: http://www.un.org/apps/news/story.asp?NewsID=36040&Cr=mdgs&Cr1

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Assessment of the Crown Fire Hazard of *Pinus densiflora* based on the Crown Fuel Characteristics in Korea

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Abstract

The objective of this study was to assess the crown fire hazard of *Pinus densiflora* forests in Korea based on its crown fuel characteristics (moisture content, crown base height and crown bulk density). The study sites were located in five areas, namely Youngju, Bonghwa, Yangyang, Daegu and Goryeong. Ten representative sample trees were destructively felled in each area to analyze the crown fuel characteristics. One focus of this study was to compare the crown fuel characteristics of the stands with forest tending works (Youngju) and the control stand (Bonghwa). Furthermore, comparison between the crown fuel characteristics of *Pinus densiflora* found in Gangwon province (Gangwon type) and Central region (Jungbu type) was conducted. Crown fuel characteristics based on the results in the five study areas were analyzed and allometric equations for crown fuel load estimation were also developed. These information will be used in the development of crown fire hazard map using Geographic Information System (GIS).

Introduction

Pure stand forests in Korea are widely distributed. These stands are very dense because thinning operations are not being done in these forests. Therefore, forest fire hazard is very high and abundant. As a result, burned and damaged properties, human casualties and forest ecosystem degradation caused by serious wild fire are gradually increasing in Korea.

The distributions of *Pinus densiflora* stands in Korea are approximately 25% of the total forested area. However, these forests are threatened to be extinct (Korea Forest Service, 2009). One of the major causes is the abundance of forest fire. The needles and branches of this type of forest are characterized of being flammable. Studies on the crown fuel characteristics of *Pinus densiflora* are limited and insufficient. Therefore, study on crown fuel characteristics is urgently needed to suppress the crown fires that are frequently occurring in *Pinus densiflora* stands. Thus, the objective of this study was to assess the crown fire hazard of *Pinus densiflora* forests in Korea based on the crown fuel characteristics (moisture content, crown base height and crown bulk density).

Methodology

The sample trees were cut from 0.2m above the ground for each sampled tree. Other measurements that were collected were tree total height, crown base height, crown width, crown length, diameter at breast height (DBH) and age. The biomass were categorized into stems, needles, branches (<0.5cm, 0.5-1cm, 1-2cm, 2-4cm, and >4cm diameter) and the green weight of these fuel components were also measured. This method was used by the different scientist on their studies (Koo et al., 2010). The moisture content of each component was analyzed using oven drying method. Samples of stems, needles and branches were dried at a temperature of 95°C for 240h and were weighed after.

In this study, the available crown fuel loads were composed of needles and fine branches less than 1cm roundwood diameter (Call and Albini, 1997; Koo *et al*., 2010). Crown bulk density, moisture content and crown base height are important crown fuel characteristics that are needed in order to predict crown fire spread (Reinhardt *et al*., 2000; Koo *et al*., 2010). The crown bulk density (CBD) was calculated as follows:

$$\mathrm{CBD}(\mathrm{kg/m^3}) = \frac{\mathrm{CFL}(\mathrm{kg})}{\mathrm{CV}(\mathrm{m^3})}$$

CFL is crown fuel load(kg) and CV is crown volume(m^3)

The allometric equations for each crown fuel load component were analyzed using the measurements of fuel in the five regions.

Results and Discussion

1) Effects of Forest Tending Works on the Crown Fuel Characteristics

The crown fuel load distribution in Youngju region (with forest tending works) were 50.3% for crown fuel(needles and >1cm branches), whereas in Bonghwa region (control), it were 62%. The average canopy bulk density observed in Youngju region was 0.19kg/m³, whereas in Bonghwa region, it was 0.30kg/m³. On the other hand, for the average crown base height, it was 5.0m in Youngju region and 3.1m in Bonghwa region.

2) Comparison of the crown fuel characteristics of *Pinus densiflora* in Gangwon type and Jungbu type

It was observed that the crown fuel load of the *Pinus densiflora* in Gangwon type and Jungbu type were almost similar for each DBH class. However, the average CBD of *Pinus densiflora* in Gangwon type was higher than the average CBD of Jungbu type because the CV of the Gangwon type trees were lower.

3) Overall crown fuel characteristics of *Pinus densiflora* in Korea.

Crown fuel load distributions of available crown fuel load of *Pinus densiflora* in Korea were 54%. Furthermore, the crown bulk density of this species was 0.37kg/m³. On the other hand, the crown bulk density of available crown fuel load was 0.2 kg/m³.

4) Allometric equations of the crown fuel load of *Pinus densiflora* in Korea.

Allometric equations were developed based from the 50 sample trees to estimate crown fuel load components of *Pinus densiflora* in Korea. It was observed that the R^2_{adj} values of the developed allometric equations were very high.

Acknowledgements

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Bush Fire Management & Cooperation

산불관리와 협력(체제)

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Abstract

Forest fires in addition to economic losses of forest resources, degradation of ecosystems, hwangyeongohyeomdeung huge collateral damage of the importance of preventing the cursor not to mention the two times. However, forest fire prevention activities, no matter how thoroughly even accidentally fires can occur naturally or artificially not only in the event of fire quickly and efficiently to minimize the damage evolution in action must be taken to cardiovascular. Therefore, a wildfire that the Forest Service, including the other organization's activities of the faithful and active suppression are required. Had already occurred in 2000 East of the wildfire problem, derived by analyzing the case and looking for ways to improve its fire suppression and efficient to the following suggestions to

1. Faithful self-role
   ○ integrated command structure, even within the respective work on the actual mutual recognition of each institution by
   ○ Each agency in performing its duties for the leadership of directors fulfill any integration
2. Fire suppression system, improved organizational
   ○ Fire suppression equipment permanent installations, such as Australia RFS (Rural Fire Service)
   ○ Take a morale of the firefighter's institution(the stability of employment-related)
3. For fire suppression is the sole cause notice tries to "Forest management"

1. 개요

일일 대응능력을 초과하는 대규모산불, 24시간 이상되는 산불 또는 동시 다발의 산불 발생시 산림청을 포함한 산불진압 유관기관간 유기적인 협력체제

구축으로 산불로 인한 인적·물적 피해를 최소화하는 방안을 제시하기 위하여, 먼저 2000년 4월 동해안 산불사례로부터 문제점을 도출하고, 효율적인 방안을 강구해 보고자 한다.

2. 산불사례

2-1 발생개요

2000. 4. 6 12:30 고성군 현내면 3GP 북방한계선 산불을 시작으로 고성 토성, 강릉 사천, 삼척 근덕으로 이어지는 동시 다발 산불이 이어서, 삼척 원덕 및 미로, 고성 거진, 동해시 일원, 그리고 삼척 도계지역에서 추가 발생되면서 강원도 동부지역 전체가 대형 산불로 휩싸였고, 결국 대형재난지역으로 선포됨.

2-2 산불피해 <피해액 : 총 1,072억원>

○ 산불발생 면적 : 23,138ha (4. 24 항공촬영)
- 고성 : 2,696 (12%), 강릉 : 1,447 (6%), 동해 : 2,244 (10%), 삼척 : 16,751 (72%)

○ 인 명 : 17명 (사망 2, 부상 15)
- 사 망 : 강릉, 삼척 각 1명,
- 부 상 : 강릉 4명, 동해 2명, 삼척 8명, 고성 1명

○ 이재민 : 299세대 850명
- 고성 : 70세대 206명, 강릉 : 159세대 465명, 동해 : 16세대 47명, 삼척 : 54세대 132명

○ 재산피해
- 건축물 : 814동(주택390, 부속사 283, 축사 129, 공장 6, 기타6)
- 가 축: 6,601마리(소31, 돼지259, 닭1,869 염소166, 개133, 꿀벌3,540, 사슴80, 기타523)
- 영농자재 : 농기계(1,328대), 종자, 비닐하우스등 6종
- 기타 : 송이(31톤), 장뇌(134천본), 공공시설등

2-3 복구비용 <총복구비 589억원>

○ 직접지원 : 30,069백만원
- 보조20,849(69%),의연금2,818(10%),융자 5,515(18%), 자부담887(3%)

○ 이재민 구호 : 3,384백만원 (보조 566, 의연금 2,818)

○ 주택복구 : 15,335백만원 (321동) - 보조 9,495, 융자 5,006, 자부담 834

○ 농업시설 : 4,774백만원 - 보조 4,720, 융자 451, 자부담 53

○ 수산시설 : 584백만원 (보조 526, 융자 58)

○ 산림응급복구 : 5,992백만원 (전액 보조)
※ 산림항구복구비(별도) : 188,287백만원(국비90% 지방비10%)
○ 간접지원 : 28,885백만원
○ 표고시설 : 8,300 (보조 2,400, 융자 2,800, 자부담 3,100)
○ 영농자금(융자) 10,000, 작목개발(융자) 2,000
○ 긴급구조경비(보조) 477
○ 공장지원 : 7,601백만원(융자 5,088, 자부담 2,513)
○ 기타시설 : 507백만원 (보조 249, 융자 258)

2-4 교훈 및 개선방향

구분	문제점	개선사항
지휘체계	● 각 기관의 입장차이로 통합지위체계가 존재함에도 지휘체계가 일원화되지 못함 ● 산불전문가가 아닌 산불 통합지휘자 원활한 지휘 및 작전수행 미흡	● 명확한 산불진화통합지휘체계 확립[1] ● 각 기관에 대한 적극적인 홍보 ● 산불에 대한 전문지식자의 양성 ● 산불진압 전문가를 참모로 활용
상호협조	● 소방의 최초 각지(覺知) 산불발생 정보가 지방자치단체등 수보(受報)기능 미흡으로 신속 전파곤란 ● 산불신고 초기부터 정보공유 미흡으로 원활한 상호협조가 되지 못함. ● 산불진압범위에 따른 상호불신 ex) 소방은집불진압에만,산림관련자는 산불진압에만 관심이 있다	● 소방상황실에서 각지(覺知)한 산불 발생정보의 신속한 전파, 보고 등 정보공유에 대한 매뉴얼 및 시스템 개선 ● 정보공유에 대한 매뉴얼 및 시스템 구축의 필요성 ● 협조체제 구축외 진압책임범위 상호인정.
정보교환 및 소통	● 산불진화의 특성상 필요한 헬기가 각 기관장들에 의한 다른 명령으로 인하여 원활한 소통이 이루이지 못하고 있음.(지휘권과의 문제도 존재함.) ● 통제단에 유관기관의 연락관이 상주하지만, 현장간의 연락은 채널이 틀리기 때문에 교신이 힘듬. ● 헬기간 무선주파수 상이로 통신 미흡	● 산불진화통합지휘자의 지휘통제하에 헬기운용 ● 재난시 공통주파수 활용

[1] 산불진압지휘체계의 법적근거는 산림보호법(법률제 9763 호)(제정 09.6.9, 시행 10.3.10)로 정립되었음

3. 산불진압 책임 등

3-1 관련 법령

○ 산림보호법(제33조[2], 제37조[3], 제38조[4] 및 제39조[5])

○ 재난 및 안전관리 기본법(제2조[6], 제3조[7], 제49조[8], 제50조[9], 제52조[10])

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[2] 산림청장은 산불의 효율적인 예방·진화체계를 마련하여야 하며, 지방자치단체의 장과 지방산림청장은 이에 따라 산불을 예방하고 산불이 발생하면 진화하여야 하며, 산불에 대비하여 산불 예방과 진화에 필요한 인력, 장비 및 예산을 확보하는 등의 조치를 하여야 한다.

[3] 산림청장 및 국유림관리소장 또는 지방자치단체의 장은 산불의 규모에 따라 산불진화를 위한 통합지휘권을 갖고 진화하여야 한다.다만, 산불이 국유림·공유림 또는 사유림에 걸쳐 발생하면 특별자치도지사·시장·군수·구청장이 통합지휘하여야 한다.(산림보호법 제37조)

[4] 산불진화를 통합지휘하는 지방자치단체장 및 국유림관리소장은 산불이 발생한 현장에 산불현장 통합지휘본부를 설치하여 산불진화를 지휘하고 진화대원에게 진화에 필요한 명령을 할 수 있고, 산불유관기관의 관계관을 소집하여 산불현장대책회의를 개최하고 기관별 임무를 부여하여야 한다.(산림보호법 제37조)

[5] 산불현장 통합지휘본부장은 산불진화와 관련하여 필요하다고 인정되면 소방관서, 경찰관서, 군부대 및 대통령령으로 정하는산림관련기관 및 단체에의 장에게 산불진화, 현장 통제 등에 필요한 장비 및 인력의 협조를 요청할 수 있으며, 요청을 받은 기관 및 단체의 장은 특별한 사유가 없으면 이에 적극 협조하여야 한다.(산림보호법 제39조)

[6] 재난을 예방하고 재난이 발생한 경우 그 피해를 최소화하는 것이 국가와 지방자치단체의 기본적 의무임을 확인하고, 모든 국민과 국가ㆍ지방자치단체가 국민의 생명 및 신체의 안전과 재산보호에 관련된 행위를 할 때에는 안전을 우선적으로 고려함으로써 국민이 재난으로부터 안전한 사회에서 생활할 수 있도록 함을 기본이념으로 한다.

[7] 산림에서의 화재도 재난의 하나로서 관리되고 있다.(재난및안전관리기본법 제3조)

[8] 긴급구조에 관한 사항의 총괄ㆍ조정, 긴급구조기관 및 긴급구조지원기관이 하는 긴급구조활동의 역할 분담과 지휘ㆍ통제를 위하여 소방방재청에 중앙긴급구조통제단(이하 "중앙통제단"이라 한다)을 두고, 소방방재청장이 단장이 되며, 중앙통제단장은 긴급구조를 위하여 필요하면 긴급구조지원기관 간의 공조체제를 유지하기 위하여 관계 기관ㆍ단체의 장에게 소속 직원의 파견을 요청할 수 있다(요청을 받은 기관ㆍ단체의 장은 특별한 사유가 없으면 요청에 따라야 한다.) 그리고 중앙통제단의 구성ㆍ기능 및 운영에 필요한 사항은 대통령령으로 정한다.(재난 및 안전관리기본법 제49조)

[9] 지역별 긴급구조에 관한 사항의 총괄ㆍ조정, 해당 지역에 소재하는 긴급구조기관 및 긴급구조지원기관 간의 역할분담과 재난현장에서의 지휘ㆍ통제를 위하여 지역통제단장을 두며 지역통제단에는 각각 단장 1명을 두되, 지역통제단장은 긴급구조를 위하여 필요하면 긴급구조지원기관 간의 공조체제를 유지하기 위하여 관계 기관ㆍ단체의 장에게 소속 직원의 파견을 요청할 수 있고(이 경우 요청을 받은 기관ㆍ단체의 장은 특별한 사유가 없으면 요청에 따라야 한다.) 지역통제단의 기능과 운영에 관한 사항은 대통령령으로 정한다.(재난 및 안전관리 기본법 제50조)

[10] 재난현장에서는 지역 긴급구조통제단장이 긴급구조활동을 지휘(치안활동과 관련된 사항은 관할 경찰관서의 장과 협의)하며 재난현장에서 인명의 탐색ㆍ구조, 긴급구조기관 및 긴급구조지원기관의 인력ㆍ장비의 배치와 운용, 추가 재난의 방지를 위한 응급조치, 긴급구조지원기관 및 자원봉사자 등에 대한 임무의 부여, 사상자의 응급처치 및 의료기관으로의 이송, 긴

○ 소방기본법[11] (제2조)

3-2. 기타 규칙, 예규등

○ 긴급구조대응 활동 및 현장지휘에 관한 규칙(소방방재청)
○ 현장통합지휘본부장 임무 매뉴얼 - 산림청
○ 산불현장통합지휘지침 - 산림청
○ 산불진화기관의 임무와 역할에 관한 규정(공동예규) - 산림청

3-3. 산불진압 전담 및 유관기관

○ 산림청 및 지방산림청
○ 지방자치단체(시・도 및 시・군・구)
○ 긴급구조기관(소방방재청, 소방본부 및 소방서)
○ 긴급구조 지원기관 (첨부2)

3-4. 통합지휘본부 설치 산불 형태

○ 대형 산불이나 일일 대응능력을 초과하는 동시다발산불로 인한 재난성 산불[12] 발생시 산불진화 및 이재민 발생, 고립지역 구호 등 재난상황

4. 산불현장지휘

4-1. 지휘절차

○ 지휘권은 산림보호법 및 관련 규정에서 정한 절차에 따른다.
○ 산불현장의 현장통합지휘는 산림보호법 제37조 및 같은 법 시행령 제25조

급구조에 필요한 물자의 관리, 현장접근 통제, 현장 주변의 교통정리, 그 밖에 긴급구조활동을 효율적으로 하기 위하여 필요한 사항에 관하여여 지휘한다. 그리고 중앙통제단장은 대통령령으로 정하는 대규모 재난이 발생하거나 그 밖에 필요하다고 인정하거나 시 · 도긴급구조통제단장은 필요하다고 인정하면 직접 현장지휘를 할 수 있으며 재난현장에서 긴급구조활동을 하는 긴급구조요원은 현장지휘를 하는 각급 통제단장의 지휘 · 통제에 따라야 하며 통제단장은 재난현장의 긴급구조 등 현장지휘를 효과적으로 하기 위하여 재난현장에 현장지휘소를 설치 · 운영할 수 있으며, 긴급구조활동에 참여하는 긴급구조지원기관의 통합지휘본부장은 현장지휘소에 대통령령으로 정하는 바에 따라 연락관을 파견하여야 한다.(재난 및 안전관리기본법 제52조)

11) 산림은 소방대상물의 하나로서 화재를 예방, 경계, 진압하여야 하는 행정 대상물이다.(소방기본법 제2조)

12) 재난성 산불이란 산불로 인하여 다수의 인명 사고와 가옥 피해가 발생하고 산림 생태계에 심각한 영향을 주는 산불을 말한다. (「산불재난」 위기관리 표준매뉴얼. 행정안전부·산림청 2010. 8.)

의 규정에 따른다.

- 산불현장에 출동한 유관기관(소방, 경찰, 군부대 등)의 선임지휘자는 통합지휘본부장의 지휘에 따라야 하며 통합지휘본부에 연락관을 상주시켜야 한다.

○ 지휘권은 공식적인 절차를 통해서 이양한다.

○ 지휘권 이양시 변경내용은 현장 대응요원 전체와 관계기관에게 전파

○ 통합지휘권은 자치단체장 및 국유림관리소장으로 일원화하며 산불의 규모·복잡성 등을 고려하여 임무・역할을 위임할 수 있다.

- 위임받은 임무・역할은 단일한 계통으로 행사되도록 한다.
- 임무・역할을 위임받은 자는 소관사항에 대해서만 임무를 수행하여야 하고, 다른 임무를 부여받은 자의 소관사항에서 오류가 발견되면 통합지휘본부장 또는 다른 임무를 부여받은 자를 통해서 시정 하도록 해야 한다.

○ 현장지휘는 공식 지휘계통인 산림과장-시장・군수-시・도지사에 의해 이행되고, 이외의 간부는 도착순서와 담당업무를 고려하여 보좌 또는 부여 받은 임무를 수행・지원하여야 하고 부여된 임무 외 다른 임무에 관여할 수 없다.

○ 현장도착 간부는 현장통합지휘본부장에 의해 임무지정을 받을 때까지는 산불현장 통합지휘본부에 대기하여야 하며, 승인 없이 이탈할 수 없다.

4-2. 산불규모별 현장지휘권자

산불 규모	설명	산불현장통합지휘본부장 (현장지휘관)	통합지휘 본부장보좌
중소형 산불	관할지역에 발생한 중소형 산불	특별자치도지사 또는 시장 · 군수 · 구청장 또는 위임받은 자	시・군 산림부서 장
		※ 단, 국유림 발생 산불은 국유림관리소장이 담당	보호담당 주무
대형 산불	대형 산불[13] 또는 둘 이상의시·군·구에 발생한 산불 또는 동시다발산불	시・도지사 또는 위임받은 자	시・도 산림부서 장
그 외	둘 이상의 시・도에 발생한 산불	산림청장 또는 위임받은 자	지방산림청장

* 산림보호법 제37조 및 동법 시행령 25조 수정재구성

[13] 산림피해면적이 100만 제곱미터 이상 또는 24시간 이상 지속되는 산불(산림보호법 제25조)

5. 기관간 대응절차

5-1. 산불시 전체 대응 업무 및 관련기관

기관	대응단계	
	단계	임무
기관별 상황실 (시도상황실)	상황각지 (119수보)	신고접수 및 유관기관 전파, 상급기관 보고 (관할소방서 출동명령)
산불현장 통합지휘권자 (지방자치단체장 및 국유림관리소장)	중소형	• 현장지휘권 인계(산림부서장 또는 산림담당직원 → 시장・군수・구청장) • 산불현장 통합지휘본부장 설치・운영 • 기관별 상황실 및 산림청 보고
	대형	• 현장지휘권 인계(시장・군수・구청장→시・도지사) • 기관별 상황실 및 산림청 보고
지방산림청/ 지방자치단체	중소형	• 진화계획 수립 - 산불진행상황, 기상・지형・임상 등 고려 • 진화조 편성 및 현장배치 • 현장상황을 수시로 파악하여 대응조치 강구 • 필요시 진화자원(헬기, 인력) 추가 지원 요청 • 현장대책본부 설치 및 대책회의 개최 - 진화계획, 진화반 편성, 보급방안 등 토의 • 추가동원자원 현장배치(현장상황 수시파악, 대응조치 강구) • 보도자료 배포 및 대언론 브리핑 • 보급 및 유조차 지원방안 강구 • 진화자원 추가요청 및 진화조직 재편성(대형산불확대 우려시)
	대형	• 현장대책본부 설치 및 대책회의 개최 - 진화계획, 진화반 편성, 보급방안 등 토의 • 진화단 재편성 및 현장배치(상황 수시파악, 대응조치 강구) • 보도자료 배포 및 대언론 브리핑
	야간 산불 진행	• 야간진화계획 수립 • 진화조 재편성 및 현장배치(진화 곤란시 감시인력 배치) • 보도자료 배포 및 대언론 브리핑 • 현장상황 및 진화대원 안전 수시확인(진화대장,조장 활용)

산항본부	중소형	• 헬기 출동준비 및 이륙요청 • 투입예정 진화헬기의 파악 및 투입 조치 • 헬기 급유지원 체계 확인 및 계류장 선정
	대형	• 다기관 헬기 진화 시에는 공중지휘기 운영 • 대형산불 발생시에 공조체계 강화를 위하여 현장대책본부에 공중진화반 배속
소방 현장지휘자	중소형	• 현장지휘소 설치(가급적 통합지휘본부내에 설치) • 시도상황실 보고 및 전파 • 선착 현장지휘자 산하 소방대원 지휘권 선언 (산불현장 통합지휘본부장 도착시 지시에 따른다.) • 상황파악 및 소방대 출동 (각지 사항 보고, 전파) • 기상상태 등을 감안, 헬기 지원 요청 검토
	대형	• 소방업무 현장지휘권 인계(소방서장 → 시도지사)
소방대	중소형	• 현장상황 수시 파악 및 안전한 퇴로 확보 • 진화작전 및 진화계획 구상 • 현장 집결지 통보(출발지가 다른 경우) • 차량은 접근·퇴출이 용이한 곳 주차(필요시 주차요원 배치) • 간이 현장지휘본부 설치(진화지휘차량) - 산불발생 원인조사 및 가해자 검거반 운영(경찰협조) • 산불 규모 및 진행상황 보고(대책본부 및 유관기관) • 화재진압, 요구조자 발생시 구조, 구급(응급처치), 이송 및 응급조치
경찰		• 현장도착 후 통합지휘본부장보고, 현장통제, 증거확보
의료기관		• 출동대기
전기/통신		• 현장도착 후 통합지휘본부장 보고, 전기/통신 차단
군부대		• 산불진압대 지원

※ 상기 나열된 대응업무는 순서와 무관함.

5-2. 산불 대응절차

가. 신고접수 · 지령전파 단계

○ 신고접수 : 119 상황실 또는 각 행정기관

- 신고접수한 119 상황실 또는 각 행정기관은 시장·군수·구청장과 지방산림청 및 소방청상황실에 보고·전파
- 그 밖의 관계 행정기관이 수보했을 경우는 산림청·긴급구조기관(시도상황실)·유관기관 등에게 통보.[14)]

○ 출동지령

- 산화발생 상황을 전파 받은 시장·군수·구청장과 지방산림청장은 산화진화대 출동지령 및 유관기관의 지원 가능자원 파악
- 시도상황실은 관할 소방서에 소방대 출동 지령

○ 유관기관 등에 상황 전파

- 전파대상 : 군부대, 지방경찰청, 한국전력공사, 한국가스공사, 한국가스안전공사, 한국전력공사, 한국전기안전공사, 한국통신(KT), 상수도사업본부, 응급의료센터, 응급의료정보센터(1339) 등

나. 현장 대응

○ 산불 현장에 선착한 공무원이 최초의 지휘관이 되며, 통합지휘본부장은 현장통합지휘본부를 설치하고 출동 산불진화대원 및 관계 기관에게 알림.

○ 시·군 산불현장 통합지휘본부 설치

- 다수 기관 및 지자체가 참여시 산불통합지휘권자 지휘하에 현장의 참여한 기관들이 함께 통합대응을 위한 산불현장 대책회의를 개최하여 기관별 임무를 부여, 산불진화계획 등을 수립함.
- 필요시 해당지역 주민이나 그 지역 안에 있는 사람을 대피시킴.[15)]
- 통합지휘권자는 대응요원의 급식, 휴식, 샤워시설 등 기본 처우를 마련해야 하며, 이에 필요한 물품의 지원 등 제반사항은 해당 지자체에서 수행하여야 함.
- 현장참여 유관기관이 추가 산불진화와 관련하여 진화자원이 필요하다고 인정되면 통합지휘본부장은 각 소방관서, 경찰관서, 군부대 등 유관기관에 산불진화, 현장 통제 등에 필요한 장비 및 인력의 협조를 요청할 수 있으며 요청을 받은 기관 및 단체의 장은 특별한 사유가 없으면 이에 적극 협조하여야 함(소속기관 진화자원이 투입한 경우에는 그 사실을 통합지휘본부장에게 알려 통합적 자원관리가 되도록 해야 하며, 통합지

[14)] 재난및안전관리기본법 제18조 2항

[15)] 재난및안전관리기본법 제40조 1항

휘본부장은 경찰에게 동 사실을 전달하여 신속히 현장에 자원이 도착할 수 있도록 협조 요청하여야 한다.)

○ (소방) 현장지휘소 설치[16)]

- 소방현장지휘관은 가시적인 지휘위치에 차량을 위치시켜 최대한 사고 현장을 볼 수 있도록 한다. 예하 인원에게 위치를 통보한다.
- 소방현장지휘관은 상황실에 지시사항을 보고하고 필요시 상호 교신을 한다. 지휘 명령권은 정식으로 위임되거나 위임된 것으로 가정되며 그렇지 않은 경우 혼란이 야기된다.
- 현장지휘소 조명을 설치하고 통신장비들을 설치하며 가능하다면 휴대용 테이블과 지도, 경방계획도를 설치한다.
- 소방지휘관(소방 연락관)은 산불현장통합지휘본부에 고정근무를 하며 통합지휘본부장의 지휘에 참여하고 소관사항에 관한 사항은 수집 보고·전달한다.

○ 상급기관 보고(산불상황 보고 및 전파)

- 통합지휘본부장은 산불진화 상황을 시.도, 산림청, 유관기관에 보고.전파하여야 한다.
- 소방현장지휘관은 산불이 발생한 경우에 시도상황실(통제단장)에게 보고하여야함.[17)]
- 지원이 필요한 때 시ㆍ도 긴급구조통제단장(시도상황실장)은 중앙통제단장(소방청 상황실장)에게 각각 보고하여 산불진압이 신속히 이루어질 수 있도록 하여야함.[18)]
- 지역통제단장(시도소방본부장)은 응급조치, 대피, 통행제한, 응원요청, 응급부담 등의 응급대책을 실시하였을 때는 즉시 시ㆍ도지사에게 보고하여야함.[19)]

○ 지자체 산림부서는 통합지휘본부장으로부터 상황정보 확인 및 적정 산화진화단 투입

- 현장출동시 출동한다는 것과 도착 즉시 출동인력, 보유장비 등을 통합지휘본부장에게 통보하고 통합지휘본부장은 산불통합지휘본부 설치시까지 현장도착 자원을 통합 지휘함
- 소방현장지휘관으로부터 산불현장의 안전상태 파악

○ 현장접근 통제 실시[20)]

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16) 재난 및안전관리기본법 제52조 6항

17) 긴급구조대응활동및현장지휘에관한규칙 제4조 1항

18) 긴급구조대응활동및현장지휘에관한규칙 제4조 3항

19) 재난 및안전관리기본법 제48조 1항

20) 산불및안전관리기본법 제43조 1항

- 소방은 소방활동구역을 위해 제1통제선을 설치하고,
- 경찰은 화재진압 및 현장구조활동 관계자 이외의 접근을 통제하기 위해 제2통제선을 설치함.[21)]

○ 경찰은 현장통제, 교통통제, 치안 등에 필요시 인력추가 투입
○ 한전, KT 등 긴급구조지원기관은 전화, 통신장비, 전기조명시설, 전력 등 현장대응에 필요한 물자 지원

다. 종료단계

○ 뒷불 감시
○ 인원, 장비 점검
○ (지방)산림청, 지방자치단체 및 소방, 경찰은 사고원인 조사
○ 지휘권 이양 - 복구 자료 인계
- 지자체 사고수습주무부서는 산불피해 결정 및 이재민 지원방안 강구
- 사고원인에 따라 보상·배상·구상권 청구

6. 효율적 산림보호를 위한 제언

6-1. 자기역할을 충실히

○ 통합지휘체계 안에서라도 각각 개별법에 의한 각 기관의 업무 상호인정
○ 각 기관자체 임무수행시라도 통합지휘자의 지휘내용 충실히 이행

6-2. 산불진압 조직체계 개선

○ 호주의 RFS[22)] 같은 상설 산불진압기구 설치. (과거의 영림서 부활 또는 가칭 산불소방서 개청)
○ 산불진화단원(산림보호법 제41조)의 사기진작을 위한 제도 강구(고용의 안정성관련)

6-3. 산불진압은 영림(營林), 육림(育林)의 한가지라는 대의명분 공고(鞏固)[23)]

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21) 긴급구조대응활동및현장지휘에관한규칙 제17조 1항
22) Rural Fire Service는 각주, 각 시마다 철치되어 있음(국내에서는 주는 산불소방청, 시는 산불소방서라 번역, 사용하고있음)
23) 공고(鞏固) : (의지 따위가) 굳고 흔들림 없다.

첨부 1. 산불진압을 위한 기관별 역할과 대응절차

■ 산불진압
가. 기능
○ 산불 우선진화순위 결정 및 신속, 적합한 산불진화 대 출동조치
나. 관련기관
○ 산림청, 지방자치단체, 소방, 군부대, 경찰, 기상청
다. 기관간 대응절차

<산림청(주관기관) 산불방지과>
○ 진화 우선순위 판단 및 조치
○ 산불진화대책회의 개최
○ 산불현장대책지원반 파견조치 파견 및 지휘 자문
○ 산불중앙사고수습지원본부 구성.운영
○ 산불현장 통합지휘본부 운영 및 활동사항 파악
○ 산불상황 접수 및 전파
○ 산불진화 상황파악 및 언론 보도(대변인) 및 담화문작성준비
○ 잔불진화 실시 및 진화완료 상황 확인

<지방자치단체(녹지.산림부서) 및 지방산림청 (운영과)>
○ 산불발생 신고 접수.확인 및 전파
○ 초동조치 및 산불진화
- 산불현장 출동 및 산불현장 통합지휘본부 설치.운영
- 현장대책회의 개최 및 진화계획 수립
- 헬기지원 요청 및 투입 조치
- 산불상황 대언론 보도
○ 진화상황 보고/전파
- 헬기의 추가투입 여부 판단 및 요청
- 유관기관 진화자원 추가 지원 요청
- 산불 확산에 따른 진화대책 수립/실행
- 적정지역을 선정하여 진화선 구축

<산림항공관리소>
○ 산불발생시 산림진화 헬기 지원
○ 다기관 헬기 진화 시에는 공중지휘기 운영
○ 대형산불 발생시에 공조체계 강화를 위하여 현장대책본부에 공중진화반 배속

<행정안전부(산불대책과)>
○ 산불예방.진화에 대한 지자체장의 산불경각심 고취 및 대응태세 독려
○ 산불방지를 위한 지자체의 현장 대응 인력지원
○ 필요시 담화문 발표와 관련된 업무협조

<국방부(산불관리지원과)· 합참(합동작전과) 및 군부대>
○ 필요 인력 및 장비(헬기 등) 지원
○ 군 비행장 이용 및 산림헬기 급유, 군 급유차량을 이용한 항공유 운송지원
○ DMZ내 산불진화 지원(합참 합동작전과)
○ 산림헬기와 공조체계 유지 및 주관기관 요청 시 산불진화 참여
○ 대형산불 발생시 공조체계 강화를 위하여 현장대책본부에 연락관 파견

<소방방재청(방호과) 및 소방관서>
○ 산불안전대책본부 운영, 상황보고 및 전파
○ 지자체의 산불진화 조치 지원
○ 산불신고 접수 시 신속 전파 및 대응 조치
○ 소방헬기, 소방차 및 소방인력 지원
○ 긴급지원 체계의 가동
○ 대형산불 발생시 공조체계 강화를 위하여 현장대책본부에 연락관 파견

<기상청(예보정책과)>
○ 산불관련 기상자료 제공
○ 기상전문가 현장파견 자문

<경찰청·지방경찰청 및 경찰서>
○ 진화인력, 경찰 헬기의 산불진화협조
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나. 관련기관
○ 산림청, 지방자치단체, 소방, 경찰, 기보유부서, 적십자사등 민간단체
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○ 산불진압대원 음식물 준비 및 제공

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○ 화재 현장 통제선 설치, 현장 및 교통 통제 등
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○ 이재민 및 산불진압등 활동자를 위한 음식등 제공 활동

■ 헬기 및 소방차량 소화용수확보, 공급을 위한 기관간 대응절차
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○ 소방차 및 헬기의 소화용수의 원활한 확보를 위한 유관기관간 조치
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○ 산림청, 지방자치단체, 소방
다. 기관간 대응절차

<산림청, 지방자치단체>
○ 헬기공급용 : 소하천등 물막이 설치를 위한 장비 및 인력동원
○ 소방차 공급용 : 소하천등 물막이 조치 및 우물, 정호활용을 위한 가반식펌프등등 확보, 협조
○ 풀장에서 직접 흡수가 곤란한 헬기의 급수장소 확보(학교 운동장 등)

<소방서>
○ 호수, 하천 및 해양등에 접근로 확보 취수활동
○ 취수차량 접근곤란시 등 가반식펌프 활용 취수활동
○ 헬기 공급 소화수용 차량배치

<경찰서>
○ 물탱크차량 신속한 통행을 위한 교통통제

■ 도시지역산불 또는 시가지 연소우려시 기관간 대응절차
가. 기능
○ 도시지역 연소로 주민안전위협 및 중요시설물 연소 방지대책수립
나. 관련기관
○ 지방자치단체, 소방, 경찰
다. 기관간 대응절차

<소방서>
○ 도시지역은 소방관서에서 초동진화를 적극 지원
○ 도시지역내로의 연소저지선 확보 진화활동

○ 연소우려 범위내 주민 구조 및 피난명령
○ 민가.시설물보호 등 대상지역에 따른 임무 및 역할 분담 및 산불방지업무 지원

<지방자치단체>
○ 연소우려 범위내 주민 피난방송 및 대피유도활동 전개

<경찰서>
○ 시가지 연소우려시 교통 및 출입통제(POLICE LINE 설치)
○ 치안유지 및 주민대피령 발령에 따른 주민의 보호

첨부 2. 긴급구조지원기관

근거	재난 및 안전관리기본법 (제3조 8호) 및 동법 시행령(제4조)
기관명	교육과학기술부, 국방부, 경찰청, 지식경제부, 보건복지부, 환경부, 국토해양부, 방송통신위원회, 기상청, 산림청, 해양경찰청, 탐색구조부대, 군부대, 대한적십자사, 응급의료기관, 응급의료정보센터, 구급차등의 운용자, 전국재해구호협회, 법 제3조 제7호의 규정에 의한 긴급구조기관과 긴급구조활동에 관한 응원협정을 체결한 기관 및 단체, 긴급구조에 필요한 인력과 장비를 갖춘 기관 및 단체로서 행정안전부령이 정하는 기관 및 단체
근거	재난 및 안전관리기시행령(제4조) 및 동법 시행규칙(제2조)
기관명	유역환경청또는지방환경청, 지방국토관리청, 지방항공청, 보건소, 지하철공사, 도시철도공사, 한국가스공사, 한국가스안전공사, 한국농촌공사, 한국전기안전공사, 한국전력공사, 대한석탄공사, 대한광업진흥공사, 한국수자원공사, 한국도로공사, 한국공항공사, 항만공사, 한국원자력안전기술원, 한국원자력의학원, 국립공원관리공단, 「전기통신사업법」 제5조에 따른 기간통신사업자로서 소방방재청장이 정하여 고시하는 기간통신사업자

Projection of Climate Change over East Asia Based on Global Downscaling with High Resolution AGCM

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Abstract

For the regional projection of future climate the dynamic downscaling technique has been used with MM5 based on the MPI-ECHO simulation for the period from 2001 to 2100 simulated based on the SRES A2 CO2 emission scenario. The future projection of warming rate is about 1.65 °C higher than the global warming rate and almost three times faster than that shown during the last century (0.61 °C/decade) over the Korea Peninsula and East Asia. As a result, the length of the summer period is projected to increase by two weeks, while the winter period is projected to decrease by three weeks in comparison to the last 100 years over the Korea. The most important thing related to global warming is not how much it will warm up but how quickly it will happen.

The precipitation shows an inter-decadal fluctuation instead of monotonic increase with carbon dioxide in the atmosphere with large variation because of heavy convective rainfalls and tropical storms. Based on the future regional climate simulation the annual precipitation increases as much as 0.07 mm/day by 2100. It means we may have about 2.6 % more precipitation annually in comparison with current annual precipitation (2.68 mm/day). However, the number of rainy day diminished by 19 days in 2100. It illustrates that we may have more precipitation and less rainy days. Consequently we may have more chance to get heavy rainfall associated with global warming.

Global downscaling with high resolution atmospheric general circulation model (GCM) has been used for regional detail climate projections over East Asia to avoid the uncertainty from choice of domain in the dynamic regional downscaling. This method has used prescribed sea surface temperature (SST) obtained from observed data as well as projected data by 4 Coupled GCMs reported in IPCC AR4. For present-day integration, AMIP SST data has been used to force the high resolution AGCM to produce present climate. The simulated climate has been examined in comparison with observed climate data. For future climate change experiment, two sets of time-slice experiments have been performed for mid-21st century and end-21st century. To force AGCM for future climate monthly mean SST anomalies are superimposed which are derived from 4 different coupled GCMs simulation based on the A1B reference scenario, onto the present-day SST boundary conditions.

INTRODUCTION

It has been a long desire to better understand the processes that determine regional climate and to evaluate regional climate change information which can be useful in impact studies and policy planning. To date, a relatively high level of uncertainty has characterized regional climate change information. This is mainly due to the complexity of the processes that determine regional climate change, which span a wide range of spatial and temporal scales and to the difficulty in extracting fine-scale regional information from coarse resolution coupled Atmosphere-Ocean General Circulation Models (AOGCMs). Coupled AOGCMs are traditionally used for generating projections of climatic changes due to the anthropogenic forcing.

Climate modeling groups around the world have been performing an unprecedented set of coordinated 20th and 21st century climate change experiments, in addition to commitment experiments extending to the 22nd century for the Inter-governmental Panel on Climate Change Fourth Assessment Report (IPCC 2007). One of the aims of these simulations is to assess the ability of the global coupled climate models to make projections of future climate change. Hence the ‘mean climate state’ of a model needs to be compared against observations. In defining the ‘mean climate state’ of a model, there are a number of ‘control run’ choices available in the IPCC AR4 archive. These include the pre-industrial or the present day trace gases runs or the 20th century all forcing runs.

The second and obvious aim of the IPCC AR4 simulations is the future projections. There are several scenarios under which projections are available. The increased emissions of CO2 have led to the enhanced heating of the earth (IPCC, 2001) and the largest simulated climate changes are due to the radiative influence of CO2 (Chen et al., 2004). This idealized scenario provides opportunity to compare responses of the different models.

Although the coupled AOGCMs are extremely useful to project the future climate under increase in atmospheric CO2 concentration, however, the horizontal resolution of present day AOGCMs is still relatively coarse, of the order of hundred kilometers, due to the centennial to millennial time-scales associated with the ocean circulation and computing requirements that these imply. Giorgi and Mearns (1991) have reported that regional climate is often affected by forcing and circulations that occur at the sub-AOGCM horizontal grid scale. Accordingly, AOGCMs are unable to capture the fine-scale structure that characterizes climatic variables. Features like fine-scale structure are useful in impact assessment studies. Therefore, a number of techniques have been developed to generate fine-scale regional climate information based on the simulation by coupled AOGCMs. According to IPCC (2001), these are referred as "regionalization" techniques and it has been classified into three categories as follows:

- High resolution and variable resolution Atmosphere GCM (AGCM) experiments;
- Nested limited area (or regional) climate models (RCMs);
- Empirical/statistical and statistical/dynamical methods.

IPCC (2001) also reports that the assessment is based on different modeling tools that are currently available to obtain regional climate information, and includes: (a) an evaluation of the performance, strengths and weaknesses of different techniques in reproducing present day climate characteristics and in simulating processes of importance for regional climate; and (b) an evaluation of simulations of climate change at the regional scale and associated uncertainties.

PROJECTION OF FUTURE CLIMATE CHANGE WITH REGIONAL DYNAMIC DOWN-SCALING TECHNIQUE

MM5 has been integrated for 100 years (2001-2100) to simulate the future climate over the East Asia (Oh et al., 2004; METRI, 2003b). The initial and boundary conditions have been derived from ECHO-G AOGCM based on IPCC SRES A2 scenario (METRI, 2003a; Oh et al., 2004). In this section the future surface air temperature and precipitation over Korean peninsula and East Asia have been discussed based on results of METRI (2003b).

Temperature is one of the most sensitive factors to human beings among many climate variables. The long-term variation of temperature has significant impact on our daily life. It also affects long-term projection on the production of seasonal goods, energy consumption for cooling and heating, determination of seeding time and blooming season, etc. Furthermore, it is one of the important key factors to determine persistence of any species in the earth's ecosystem. According to third IPCC assessment report (IPCC, 2001), the global mean surface air temperature has increased 0.6°C during the last century. Furthermore, the warming over Korean peninsula is more dominant than global average. It is recorded 1.5°C warming during the 20th century.

To understand the projection of future climate in Korean peninsula, it is necessary to review the characteristics of past temperature variation over the Korean peninsula and East Asia using observed data. Accordingly, the CRU 0.5°x0.5°grid data (New et al., 1999) for surface air temperature has been analyzed to illustrate past climate changes during the last 95 years for the period of 1901-1995 over the Korean peninsula and East Asia region (24~49 °N, 109~149 °E).

The annual mean surface air temperature (°C) over the Korean peninsula and East Asia for 95 years has been presented in Fig. 1(a) and monthly surface air temperature anomaly for recent 10 years (1986-1995) has been presented in Fig. 1(b). Temperature anomaly is calculated using climatological surface air temperature for the period of 30 years (1961-1990). Average temperature during these 95 years is noted as 7.5°C, which is slightly lower than that of other region in the same latitude zone. It might have been caused from the fact that the cold and dry northwesterly is dominant during winter season. It brings a dry and chilly air mass to this region during winter season so that it may contribute to slightly cool mean temperature compared with other region where the Siberian high is not dominant.

As shown in Fig. 1(a), the average surface air temperature of recent 10 years (1986-1995) is 7.9°C, which is 0.7°C higher than that of 1900s (1901~1910). This represents another example of the global warming trend, which is observed in the most parts of the world (Parker et al., 1994; Easterling et al., 1997; Heino et al., 1999; Plummer et al., 1999). Researchers have pointed out that the rapid warming trend since 1970s is not occurring at particular region but it is a global phenomenon (Hansen and Lebedeff, 1987), it is more significant over the Korean peninsula and East Asia as high as 0.3°C/decade. In particular, the most significant high warming is recorded in 1990s as much as 0.6°C/decade.

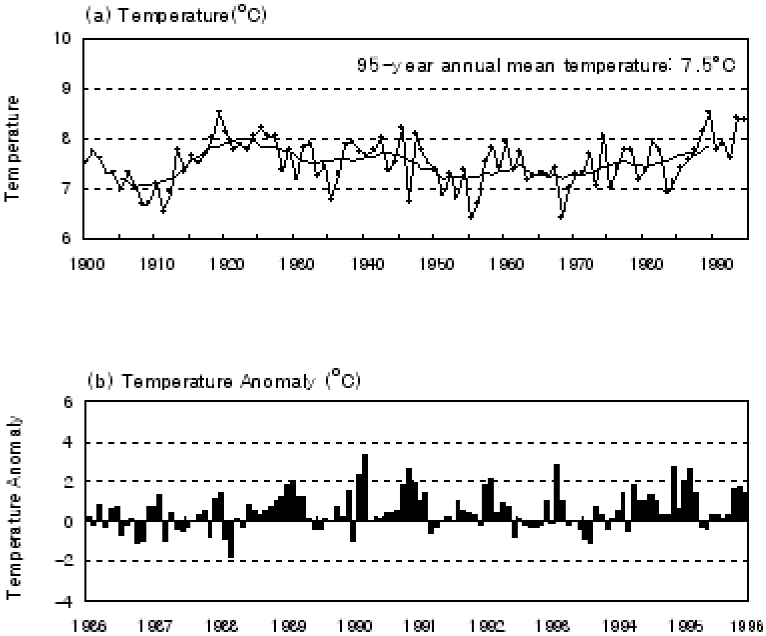

Fig. 1. (a) Annual mean surface air temperature (°C) over the Korean peninsula and East Asia for 95 years, (b) Monthly surface air temperature anomaly for recent 10 years (1986-1995). Temperature anomaly is calculated using climatological surface air temperature for the period of 30 years (1961-1990). In the upper panel the solid line represents 11 months running mean.

Fig 1(b) illustrates the different aspects of regional warming phenomena by presenting monthly mean surface air temperature anomalies from the climatological mean of 30 years (1961-1990).The largest temperature anomaly is found in 1990. Based on these results we may conclude that the Korean peninsula and East Asia is not free from the global warming trend. Recent warming trend is much more significant than previous period. It can be a result of recent Industrial Revolution.

Projection of future climate changes over Korean Peninsula and East Asia in the context of temperature changes is presented here. Fig. 2 shows the annual mean temperature changes in Korean peninsula and East Asia for the future 100 years (2001-2100) the regional climate simulation with the SRES A2 CO_2 emission scenario. From these results, it is evident that the mean warming rate over Korean peninsula and East Asia is 0.61°C/decade for the next century. This warming rate is somewhat faster than the global temperature trend presented in Table 1. Based on the ECHO global climate model simulation the global mean temperature is 19.33°C during the 2090s, which is about 3.7°C higher than 2000s. Meanwhile, the warming is 5.45°C over the East Asia during the next 100 year. It is about 1.65°C higher than the global warming.

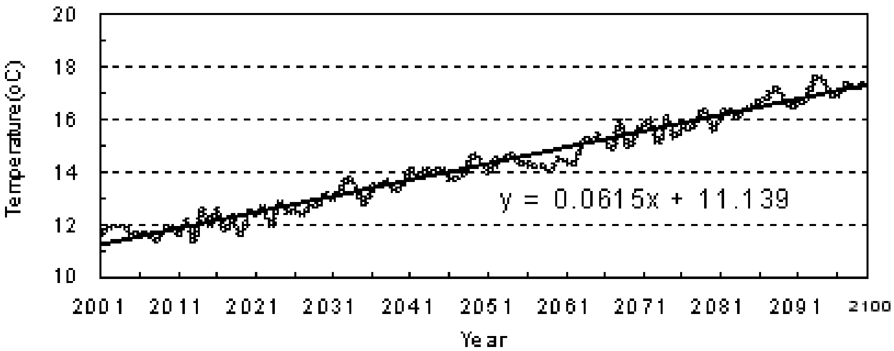

Fig. 2. Annual temperature changes in the Korean peninsula and East Asia for the next 100 years (2001-2100) by the regional climate model based on the SRES A2 greenhouse emission scenario.

Fig. 3 shows the relative changes in the daily mean, maximum, and minimum temperature for decades (selected every 20 years) in comparison with 2000s temperature. Until year 2100, there is gradual increase in these three variables. The magnitude of increase is 0.45°C, 0.34°C, and 0.56°C for the daily mean, maximum and minimum temperature respectively. It may not be significant. However, it is notable that the increase in the daily minimum temperature is somewhat larger than that of the maximum temperature. Then, we might be interested to know which season becomes significantly warm. Fig. 4 shows the mean temperature changes in autumn of 2090s, when the largest change has been recorded among four seasons in comparison with current climate. The increase in the daily mean temperature is larger than 5°C at most regions. Note that the shaded region represents temperature changes larger than 6.5°C. However, we may expect similar warming in the daily minimum and maximum temperatures (Fig. not shown).

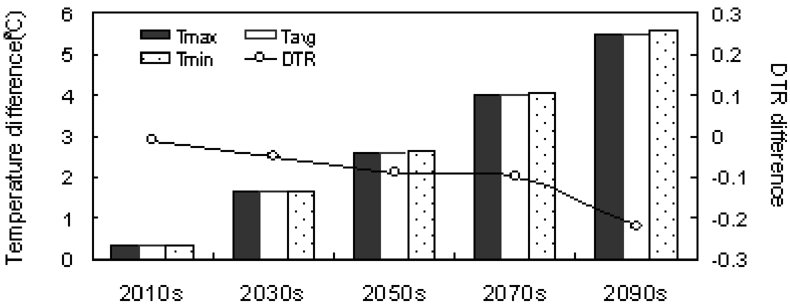

Fig. 3. Relative changes in daily mean, maximum and minimum temperature. Changes in diurnal temperature are also presented.

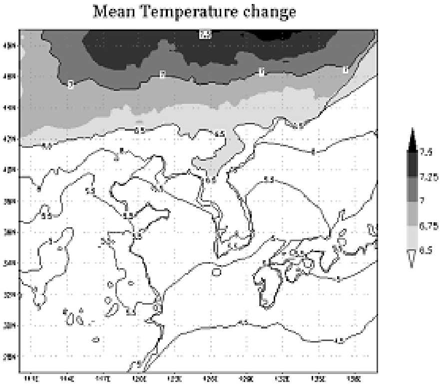

Fig. 4. Mean temperature changes in autumn of 2090s, when the largest change has been recorded among four seasons in comparison with current climate. The shaded region represents temperature changes larger than 6.5°C.

The precipitation over East Asia for the domain (24~49°N, 109~149°E) has been investigated with the CRU data for the period of 1901 to 1995. In a comparison to other meteorological variables, precipitation shows large variation because of heavy convective rainfalls and tropical storms. The annual mean precipitation is 763.5 mm and it increases as much as 3.4 mm/decade (Fig. 5a). The wettest year is 1954 with precipitation of 882.9 mm, while the driest year is recorded in 1913 with precipitation of 682.9 mm. The difference of monthly mean precipitation from the 30 years (1961-1990) mean precipitation is shown in Fig. 5b for recent 10 years from 1986 to 1995. Unlike surface air temperature, it shows a large variability due to its characteristics of spatial and temporal variation.

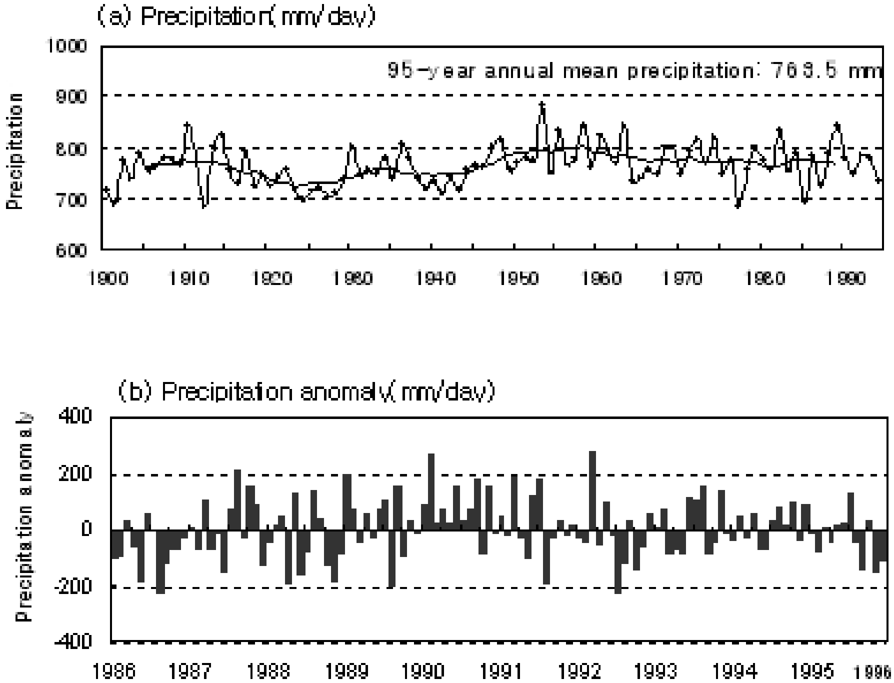

Fig. 5. (a) Annual mean precipitation during 1901~1995, and (b) monthly mean precipitation anomalies of 1986~1995. Smoothening has been done using 11-year moving average. Precipitation Anomalies are based on climatological mean of 1961~1990 over East Asia.

A projection of future precipitation over the East Asia has been presented in Fig. 6 based on the results of regional climate simulation SRES A2 scenario. It is represented in terms of annual mean precipitation (Fig. 6a) and the number of rainy days with precipitation intensity (Fig. 6b). Daily precipitation more than or at least 0.1 mm/day is considered as rainy day.

Based on the future regional climate simulation the annual precipitation increases as much as 0.07 mm/day by 2100. It means we may have about 2.6 % more precipitation annually in comparison with current annual precipitation (2.68 mm/day). However, the number of rainy day diminished by 19 days in 2100. It illustrates that we may have more precipitation and less rainy days. Consequently precipitation intensity (PI) will increase, as it is ratio of annual precipitation amount and rainy days (Fig. 6b). It means, in other words, we may have more chance to get heavy rainfall associated with global warming.

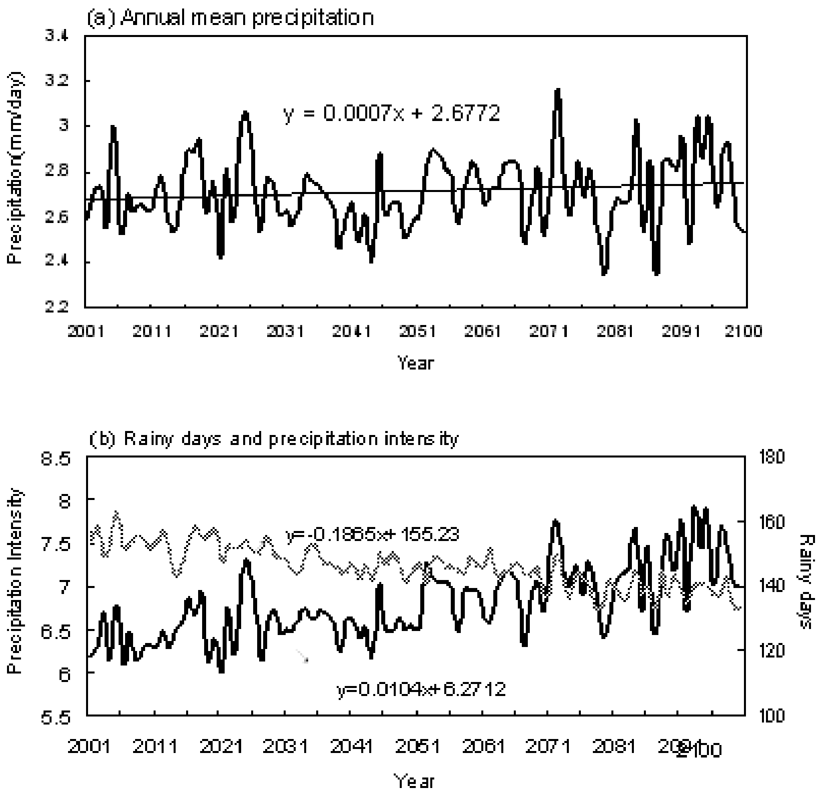

Fig. 6. (a) Annual mean precipitation (mm/day) and (b) number of rainy days (light line, right scale) and precipitation intensity(thick line, left scale) from 2001 to 2100 over East Asia.

As shown in Table 1, the decadal mean of simulated global and regional precipitation has increased gradually, although the interdecadal oscillation can be observed in the regional precipitation clearly with its increasing trend. In Korean peninsula and East Asia the precipitation has either increased or decreased during the period of 2001-2100. The precipitation has been estimated as much as 4.1 % increase during 2090s compared to that of 2000s. It is somewhat larger than the global mean precipitation increase which is estimated as 3.5 %. It has increased up to 1.9 % for 2010s compared to that of 2000s. However, it has decreased up to 1.1 % for 2030s. Subsequently it has increased up to 3.4 % for 2050s. It may reflect that there are two decadal oscillations in the simulated precipitation.

Table 1. Decadal mean and difference of simulated global and regional precipitation

Precipitation (mm/day)	Global		East Asia	
	Mean	Difference	Mean	Difference
2000's	2.85	-	2.68	-
2010's	2.86	0.4%	2.73	1.9%
2020's	2.86	0.4%	2.74	2.2%
2030's	2.87	0.7%	2.65	-1.1%
2040's	2.88	1.1%	2.61	-2.6%
2050's	2.88	1.1%	2.77	3.4%
2060's	2.90	1.8%	2.71	1.1%
2070's	2.91	2.1%	2.71	1.1%
2080's	2.93	3.8%	2.73	1.9%
2090's	2.95	3.5%	2.79	4.1%

The geographical distribution of precipitation changes during February (left panel) and autumn (right panel) in 2090s have been presented in Fig. 7. There is significant decrease in precipitation during February, while there is significant increase in autumn. During February the precipitation is decreased as much as 2 mm/day over the area of central China and over the ocean of East China Sea to south of Japan. During the autumn of 2090s, the precipitation increase is more significant over the ocean than over the land in comparison with 2000s precipitation (Fig. 7b).

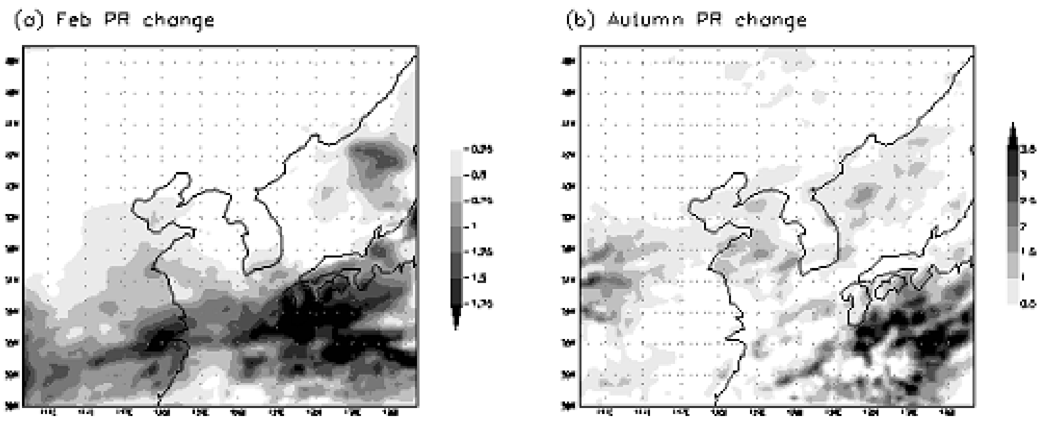

Fig. 7. Precipitation changes during (a) February and (b) Autumn in 2090s relative to 2000s. Shading indicates negative values in left panel and positive values in right panel.

PROJECTION OF FUTURE CLIMATE CHANGE WITH HIGH RESOLUTION AGCM

The weather and climate prediction using the global numerical model has been studied for a long time. Recently, the study has been performed improving the horizontal/vertical resolution in numerical modeling due to availability of enhanced computing resources. A review by Simmon and Hollingsworth (2002) showed that the increased resolution has had a positive effect on operational forecasting. This research with numerical global modeling below 30km resolution is in progress in several research groups in USA, England, Germany and so on. Especially, the Earth Simulator in Japan has performed a mesoscale resolving simulations of the global atmosphere with 10km resolution (Ohfuchi et al., 2004). So in this study, we have also examined the capability of Icosahedral-hexagonal Gridpoint Global Model (GME) in the projection of future climate change by time slice run based on the IPCC AR4 simulations by several coupled AOGCMs.

The GME model is the operational mode of German Weather Service (Deutscher Wetterdienst). It is based on uniform icosahedral-hexagonal grid (Majewski et al., 2002). The GME gridpoint approach avoids the so-called pole problem. This model can adjust the resolution, so it is possible to simulate weather and climate change over both global and regional scale. So we have experimented GME model in different horizontal and vertical resolution (10 km~240 km/40~60 layers). We have used the KISTI IBM supercomputer to simulate the typhoon prediction at various resolutions. With high-resolution (10 km) and increase in vertical level (60 layer), the model captures even the very small scale local features as shown in Fig. 8.

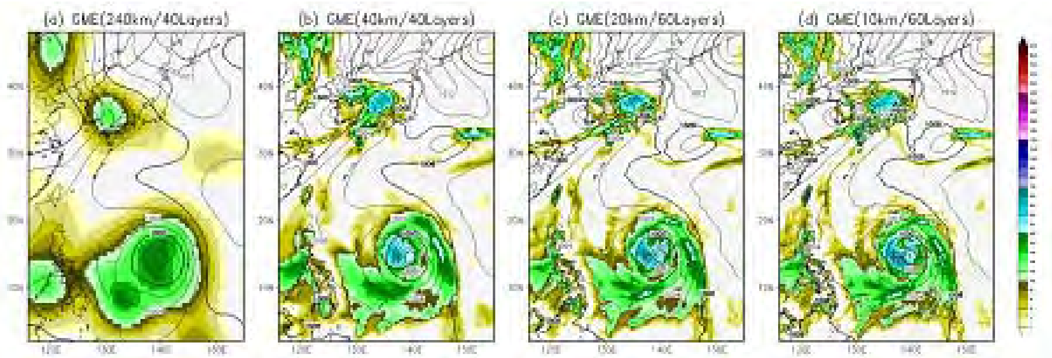

Fig. 8. Typhoon Simulations in different resolutions using GME model. (a) Precipitation and Mean Sea Level Pressure in 240 km and 40 layers, (b) 40 km and 40 layers, (c) 20 km and 60 layers and (d)10 km and 60 layers.

For the current and future regional projection with time-slice method GME model with 40 km/ 40 layers has used. For present-day integration, the prescribed AMIP SST and sea ice data has been used to force the high resolution AGCM. The simulated climate has been examined in comparison with observed climate data. For future climate change experiment, two sets of time-slice experiments have been performed for mid-21st century and end-21st century. To force AGCM for future climate a superimposing monthly mean SST anomalies, which is derived from 4 different coupled AOGCMs simulation based on the IPCC SRES A1B emission reference scenario reported in the IPCC AR4. The AOGCMs provided SST and sea ice data are CGCM3.1(t63) (Flato 2005), CNRM_CM3 (Salas-Media et al. 2006), ECHAM5/MPI-OM (Jungclaus et al. 2006), and MIROC3.2(hires) (K-1 Model Developers 2004). The horizontal resolution of CGCM3.1(t63) and CNRM_CM3 is 2.8 degree by 2.8 degree, and those of ECHAM5/MPI-OM and MIROC3.2(hires) are 1.9 degree by 1.9 degree and 1.1 degree by 1.1 degree, respectively.

For the evaluation of GME to simulate climate change the simulated climate (20C3M) for the period of 1981-2000 by GME with the monthly AMIP SST and sea ice data (Taylor et al. 2000) has been compared with observational data as well as the results of the 20th Century Climate in Coupled Models (experiment acronym ‘20C3M’) runs as reported in IPCC AR4. As recommended by the IPCC AR4 panel, the models mean climate will be defined based on the last twenty years (corresponding to 1981-2000 period) of the “all forcing 20th century runs” i.e. experiment designated as ‘20C3M’. The proposed periods of middle and end of the 21st century climate are chosen the climate of 2040-2060 and 2080-2100 from the future climate change projection by those AOGCMs, respectively. The variability of AMIP observed SST during the period of 1980-2000 has been introduced for middle and end of 21st century climate by superposing detrended AMIP SST to composite future SST data from 4 AOGCMs.

Figs. 9 and 10 show the summer (June-August) and winter (December-February) surface temperature of current, middle and end of 21st century, respectively, together with the changes of future climate from current climate. A warming has occurred over the land and it is more significant during the high latitudes at the winter hemisphere. This warming trend becomes much clearer at the end of 21st century than during the middle of 21st century.

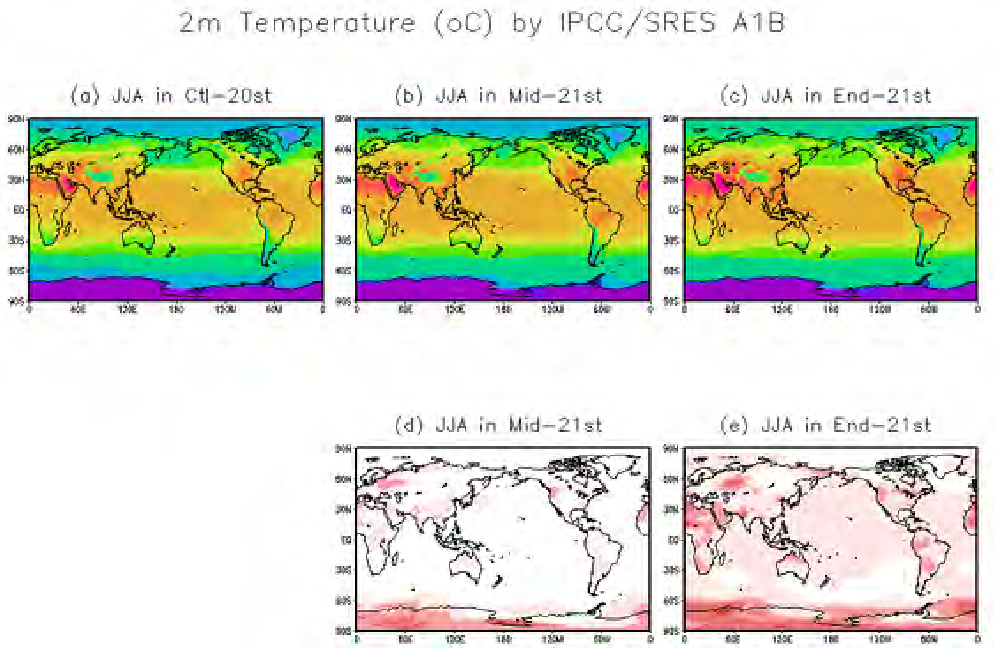

Fig. 9. Summer surface temperature of (a) 20th century, (b) middle of 21st century, and (c) end of 21st century, respectively, together with the differences from 20th in (d) and (e).

Differently from surface temperature the trend of summer precipitation does not show any organized development in future as shown in Fig. 14 except that the regional variation of precipitation during the summer in the Northern Hemisphere becomes more significant by the end of 21st century. Based on the analysis of the 22 AOGCMs in IPCC AR4 Kripalani et. al. (2007a, b) reported that the simulated spatial distribution of precipitation could be sensitive to model resolution. The high-resolution version produces more precipitation over the eastern side of the Tibetan Plateau, southern China up to Japan due to the high frequency of heavy precipitation simulated by this model.

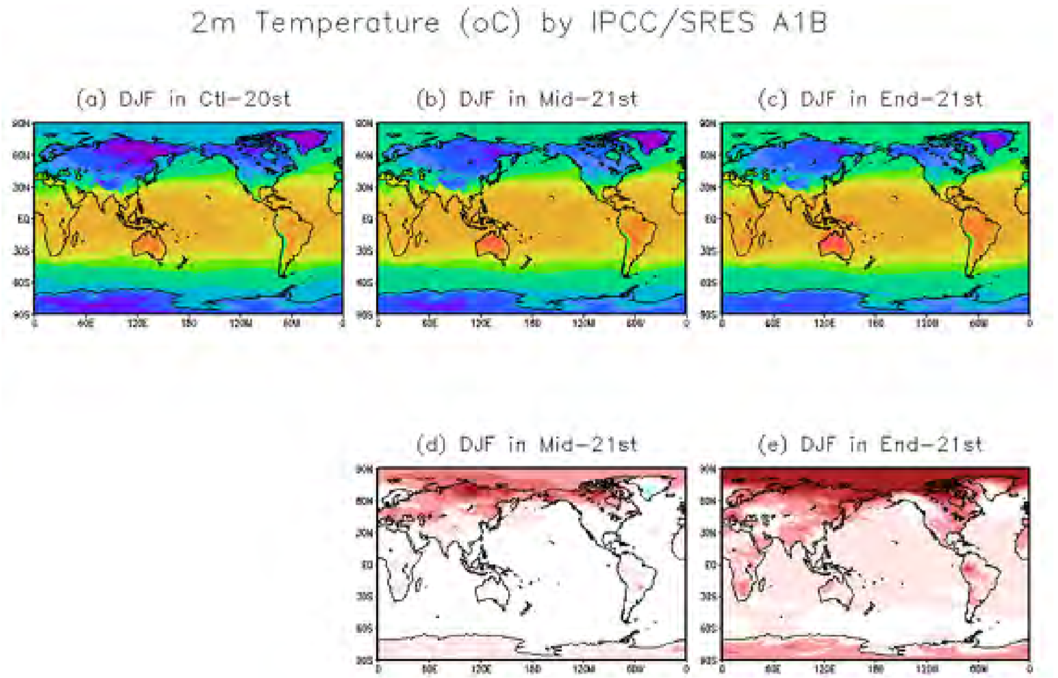

Fig. 10. Winter surface temperature of (a) 20th century, (b) middle of 21st century, and (c) end of 21st century, respectively, together with the differences from 20th in (d) and (e).

DISCUSSION AND CONCLUSION

Through a series of GCM experiments it has been observed that there is increase in surface air temperature and precipitation over East Asia during the 21st century. Although the temperature increase is well reflected by various climate models, there is a large difference in the precipitation patterns. We may have clear understanding regarding the impact of carbon dioxide reduction in the atmosphere from the comparison of simulated climate based on the IPCC SRES A2 and A1B scenario. Striking feature like enhancement of summer precipitation is well simulated by climate models (Fig. 11). It may lead to enhancement of summer monsoon. However, it requires further studies for more clarification and confirmation.

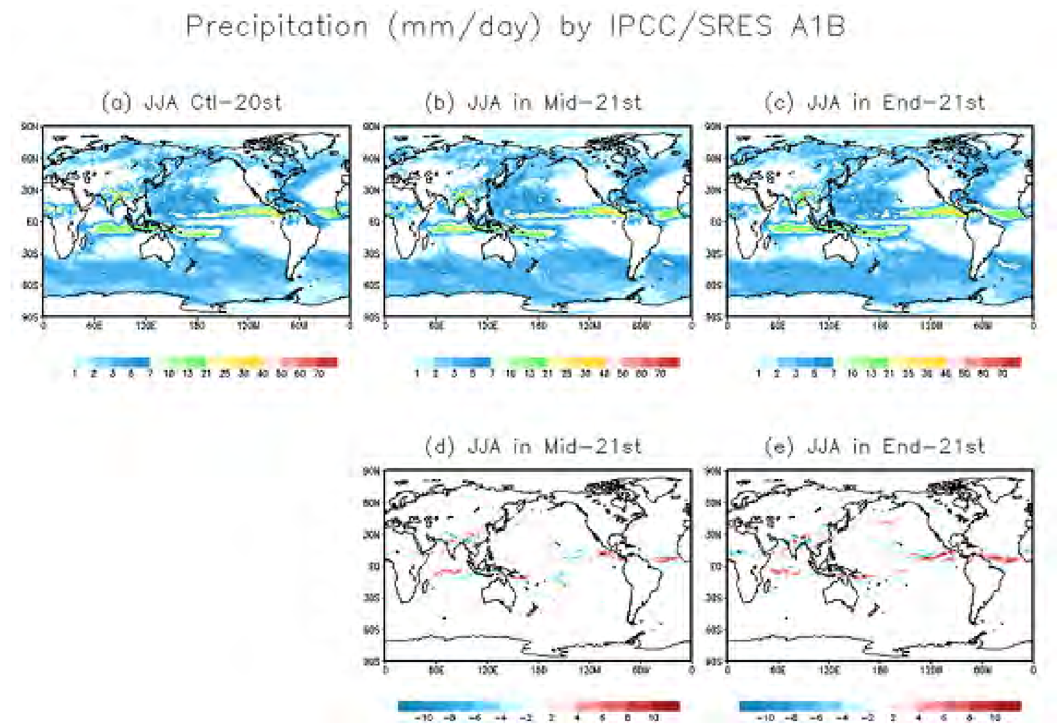

Fig. 11. Summer precipitation of (a) 20th century, (b) middle of 21st century, and (c) end of 21st century, respectively, together with the differences from 20th in (d) and (e).

Several studies have been done on regional climate change based on statistical analysis over Asia. However limited studies have been done on the future climate projection with dynamic downscaling technique over Asia. Generally, all studies indicate warming climate trend over East Asia. However, there is a considerable difference in the future precipitation changes. Recently, Oh et al. (2004) made a projection of surface air temperature and precipitation in East Asia including Korean peninsula based on the dynamic downscaling with MM5 for the 100 years (2001-2100) nested to the global projection with the MPI AOGCM based on IPCC SRES A2 scenario. This experiment results also show a significant increase in the surface air temperature in East Asia. However, the precipitation shows an inter-decadal fluctuation instead of monotonic increase as in temperature increase with carbon dioxide in the atmosphere.

This regional climate change study is based on dynamic downscaling method. To get reasonable confidence on the regional climate change information, it is required to have various regional modeling studies including time-slice runs with high resolution AGCM to avoid the uncertainty from the domain of regional dynamic downscaling. Through these efforts we may have better understanding of future climate projection and we may reduce or get rid of uncertainty which is involved in regional climate change information. Model inter-comparison studies can be helpful for this purpose. Recently there is a great concern on the extreme weather events, such as heavy rainfall and tropical cyclone. Also, many scientific challenges have been taken to reduce the uncertainty in future climate projection, such as systematic monitoring, enhancement in treatment of physical processes in the global as well as regional models, ensemble prediction, simulation with various scenarios including both direct and indirect effect of atmospheric aerosols, and consistent analysis of model projection for future climate. In future, we will have better projection for future climate changes and better understanding of the catastrophic disaster arising from greenhouse gases.

Although none of these sets of time-slice experiments is able to capture accurately the response of regional climate change, the results may provide an essential data to estimate regionally detail temperature increase and changes in precipitation pattern over East Asia including the East Asian monsoon. The results might be utilized to set up both national and regional adaptation strategies for CO_2 induced global warming.

ACKNOWLEDGEMENTS

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Vegetation Regeneration and Soil Erosion for Ten Years Following Forest Fires in Korea

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Abstract

The recovery processes in terms of vegetation and soil have been monitored in permanent plots and runoff plots for ten years. Also, the effectiveness of several soil conservation measures on runoff and soil erosion has been tested. The prefire *Pinus densiflora* forests have been successfully recovered into mainly *Quercus*-dominated forests though the speed and the pattern varies depending on various factors such as prefire species composition, burn severities and initial regeneration. Soil erosion was severe in low regeneration regions occupied by prefire young pine stands. The experiments on the soil conservation measures emphasize that fast regenerating vegetation significantly contributes to preventing soil erosion and proper hill treatment such as woodchip mulching is needed for the poorly regenerated regions immediately after fires.

INTRODUCTION

All forest fires in Korea are caused by humans (Korea Forest Service 2009). Logging and frequent forest fires from heavy forest use had been important factors causing disturbance in Korea. More than 90% of forests in South Korea are secondary forests that are less than 40-years-old (Korea Forest Service 2009). This strongly implies that until recently, there have been frequent and serious disturbances to forested landscapes (Hong 1998). In the early 1970s, however, the government implemented strong forest resource policies including changing fuel sources from wood to coal, prohibition of slash-and-burn farming, prevention and suppression of forest fires, and plantation of large areas. These policy changes have affected the recovery and successional patterns of forests throughout Korea (Northeast Asian Forest Forum 2000). Significantly, they have reduced forest losses caused by massive logging. Nonetheless, fire is still a major disturbance to forested landscapes. The consumption of wood by fires has strikingly increased since the 1990s as forest stands have developed and accumulated biomass (Korea Forest Service 2009).

The east coast forest fires, the largest recorded, occurred in April 2000 and burned a total of 23,794 ha of forested land, an area equivalent to 0.37% of the total forested area in South Korea (Ro *et al*. 2000). After the east coast fires, serious issues were raised regarding conventional forest recovery management and the capacity of natural regeneration capacity in the affected forests. The actual spatial patterns of burn severity and recovery, and their implications over large-scale landscape processes have been little studied in Korea. Most studies concerning forest fires in South Korea have mainly concentrated on initial floristic changes after fires compared to unburned areas (e.g. Kim *et al*. 1981; Kim et al. 1999), and on soil chemical characteristics (e.g. Kim *et al*. 1999). The lack of information has led to the establishment of the 'Joint Association for the Investigation of the East Coast Fires' with the support of the government. This association has subsequently investigated various aspects of disturbances and forest recovery over the range of affected forests. The considerable attention given was enough to spur various levels of studies for the impact of fires on forest dynamics in Korea.

Since the investigation immediately after the fires, the recovery processes in terms of vegetation and soil have been monitored in permanent plots and runoff plots for ten years. In addition, the effectiveness of several soil conservation measures on runoff and soil erosion has been tested.

VEGETATION IN THE FIRE YEAR AND TEN YEARS LATER

Burn severity and initial regeneration immediately after the fires

We analyzed the differential severity and post-fire recovery of pre-fire forest types of different stand age both at stand and species level. Analysis showed that pine stands were the most severely burned, while conversely pine-hardwood and hardwood stands were less vulnerable. This implied that pine forests had fire-prone characteristics.

Vegetation recovery went the opposite way; that is, the regenerating vegetation cover was 71% pre-fire hardwood stands, and 65% and 53% of pine-hardwood and pine stands, respectively. However, these recovery rates were strikingly fast, considering that investigation took place about 3 months after the fires. Fire did not initiate successional processes, but tended to accelerate the predicted successional changes by releasing pre-fire understory species that survived the fires and regenerated by sprouting. The dominant pre-fire tree species (*P. densiflora*) was susceptible to fire and not resilient enough to reestablish in competition with oak species. Contrary to pines, the abilities of oak species, mainly *Quercus mongolica* and *Q. variabilis,* to survive fires and to resprout vigorously made them dominant at most post-fire stands. These shifts in species abundance caused drastic changes to the landscape: from pine-dominated to oak-dominated stands without any notable change in species composition.

Forest regeneration for ten years

Vegetation recovery in terms of stand development and species composition have been monitored for ten years following fires. To compare the recovery process according to differential burn severities and initial regeneration classes, permanent plots were established in prefire *Pinus densiflora* forest stands. Upper layers were developed faster at the severe-burn plots than those at light-burn plots. Among plots with different regeneration classes, 'high' plots showed fast recovery developing the sub-tree layer in the seventh year, while at 'low' plots vegetation developed the shrub stage. Unlike layer development, the number of species showed slight difference with time. Species from all burned plots tends to increase with time due to the recruitment of seed plants. Species composition is highly correlated with prefire composition as plant species have been regenerated from prefire existed underground organs. *Quercus mongolica* and *Q. variabilis* are mostly dominant resulting in the replacement of *P. densiflora* at most severe burn plots except for ‘low regeneration’ plots where the abundance of *P. densiflora* is increasing fast in recent years.

SOIL EROSION AND SOIL CONSERVATION MEASURES

Runoff and soil erosion for ten years

Most forest fires occur in spring in Korea. Following fires in spring, summer monsoon damage soil surface severely. Therefore, at a prefire *Pinus densiflora* forest where severely burnt by East Coast fire in Samcheok, Korea in 2000, we have compared the relative effects of vegetation recovery and rainfall on the sediment yields and runoffs from 2003. Experiments were performed from 21 runoff plots with various level of vegetation coverage. The runoff and sediment yield have significantly decreased with time following the fire. However, significant differences of the sediment yields and runoffs among different vegetation recovery maintained during the experimental period. From the seventh year, the relative effect of vegetation recovery on both of sediment yields and runoffs exceeded the effect of the rainfall events and its effects maintained since then. This has great implications regarding the managements of the disturbed soils by severe forest fires.

Soil conservation measures

The effect of soil conservation measures, such as mulching with wood chips, seeding with native plant species and log erosion barriers (LEBs), on runoff and soil erosion were examined using runoff plots. Wood chip mulching greatly reduced runoff and sediment yields and these effects were consistent regardless of the volume of rainfall. Neither seeding nor LEBs reduced runoff and sediment yields. No positive or negative effects of mulching, seeding or LEBs on ground vegetation cover were observed. The ineffectiveness of seeding and LEBs may have been due to the steep slope, the failure of germination and establishment of seeded plants, and the small diameter of logs. Treating hill slopes with mulch should be considered where post-fire regeneration is slow and there is an absence of organic material such as litter.

CONCLUSION AND IMPLEMENTION FOR POSTFIRE FOREST MANAGEMENT

For ten years after fires, prefire *Pinus densiflora* forests have been successfully recovered into mainly *Quercus*-dominated forests though the speed and the pattern varies depending on various factors such as prefire species composition, burn severities and initial regeneration.

Soil erosion was more severe in low regeneration regions mainly occupied by prefire young pine stands. The results regarding soil conservation measures emphasize that fast regenerating vegetation contributes to preventing soil erosion and to preserving the substantial pools of nutrients in the biomass.

Therefore, the protection of topsoil should be the first consideration in fragile and unstable environments. To prevent topsoil loss, the natural regeneration of vegetion should be allowed to accumulate biomass. In addition, proper hill treatments in poorly vegetated regions should be introduced immediately after fires to control severe soil erosion.

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System for the Reduction of CO_2 Emitted from Forest Fire

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An addendum[1)] was prepared to facilitate negotiations among the parties in the tenth session of the Ad Hoc Working Group on Further Commitments for Annex I Parties under the Kyoto Protocol. The Copenhagen deal requires countries to submit the pledges to reduce the green house gases emissions by the end of January, 2011. The idea of putting a cap on the amount of CO_2 emission has though caused some developing and emerging nations like China, India, Brazil or South Africa disagree with the clauses of this addendum. Their argument is that CO_2 emission is natural when a country is industrially developing like theirs and by putting a cap in the amount of CO_2 emission; the developed nations are trying to threaten their capacity to expand. Even though all these emerging nations have been trying their best to promote the renewable sources of energy and decrease the amount of the green house gases, they do not want the development of their nation be hindered by some external force and thus are not agreeing with the attempts to make emissions cut legally binding or setting long term goals for reducing green house gases. This disagreement has caused various concerns for the whole global environment scenario.

In this paper, we present two techniques by whose implementation all the nations can come under the Kyoto protocol and the second commitment period can be implemented and global environmental problem caused by CO_2 can be reduced by a big amount.

1. Improvement of Monitoring Technique of Forest Fires and fast transmission of the message to extinguish the fire

The amount of CO_2 released every year from the forest fires is considerably higher than from other sources. In a study of 100 Mha of Canadian Boreal forest for the effects of climate, carbon dioxide concentration and fire disturbance on net biome production, net primary production and vegetation dominance by creating a model, it was obtained that the carbon balance of that region was driven by changes in fire distribution from 1948 to 2005[2)]. Even though the trees work as natural sink for carbon dioxide, there are large quantities of forest fires occurring all over the world[3] which emit CO_2 in large quantities. From the IPCC's Fourth Assessment Report, the greenhouse gases emission has increased by 70% from 1970 to 2004 to a total amount of 49 billion CO_2 tons, and out of which, CO_2 comprises of around 76.7% which accounts to about 37.6 billion tons of the total emission[4]. And from FAO's data, the average amount of CO_2 emitted from the year 1997 to 2006 from forest fires is around 9.2 billion tons, which comprises of 18.8% of the total CO_2 emission and it also states that there is an increment in the frequency of forest fires every year[3)]. While GFMC (2009) reports it to be anywhere from 7.3 billion CO_2 tons to 14.7 billion CO_2 tons[5)]. This variation in the data of the green house gas emission with such large error extent indicates that a proper measurement method is not implemented yet.

So an establishment of a technology for the detection of forest fires and the starting the extinguishing process within one hour of the detection is a must. Currently there are various satellites such as MODIS (with spatial resolution of 1km but time spacing of 2 times in a day) monitoring for forest fires but there is a big time lag between the detection and the extinguishing of the fire and even when the fire is detected it is already too late. So, newer satellites with spatial resolution of about 5m and temporal resolution of about 5 minutes should be launched for full time monitoring of the forest fire and relay of the fire alarm in real time to the required authority to start the fire extinguishing procedure within one hour of the fire outbreak. If this can be achieved, a large quantity of forests can be protected and the CO_2 released from the forest fires can be reduced by a drastic amount by decreasing the amount of the total forest fires on the earth.

Figure 1 is an example of the fire smoke, which is observed by Khabarovsk Fire Fighters.

Fig.1. Fire started breaking out almost immediately[6)].

2. Construction of Measurement Model for the Calculation of the amount of CO_2 emitted in Forest Fires

The construction of a measurement model to calculate the accurate amount of CO_2 emitted from the forest fire is very essential. Currently there are simulation models available for the calculation of the amount of CO_2 absorbed by a portion of forest according to the type of trees in the forest. Using those models to calculate how much carbon the forest would have absorbed had it been there. Furthermore, there is a satellite called the GOSAT[7)] (Greenhouse Gases Observing SATellite) which is the world's first satellite dedicated to greenhouse-gas-monitoring. GOSAT , launched by Japan Aerospace Exploration Agency(JAXA), measures the density of CO_2 and methane from 56,000 locations on the earth's atmosphere. And, there is a need for the establishing a different model (Emission model) for the precise calculation of CO_2 emitted by forest fire.

By using the mixture of above three techniques i.e. the model for calculation of CO_2 absorbed by the forest (Absorption Model), the GOSAT data and the new model for the calculation of CO_2 released because of the fire (Emission model), exact calculations of the CO_2 stored in forest and emitted in forest fires can be done.

3. Application of the above mentioned techniques 1. and 2. into CO_2 Emission Trading Scheme

The addendum states that when a forest fire occurs as a force majeure, it does not fall in the category for the calculation of CO_2 emitted, and force majeure is not intended to excuse negligence and other malfeasances. For example, in Russia there is approximately 1 billion tons of CO_2 released from forest fires and around 90% every year resulting from human carelessness and malfeasance[8)].By the application of the above two techniques, first the forest fires can be detected and extinguished early which results in the reduction of global CO_2 emitted every year.

By using the monitoring technique of forest fires and the CO_2 level measurement model as tools much more forests of the developing and emerging countries can be taken by the developed countries under forest management under emission trading scheme. With the establishment of the two techniques, there is a lesser need to worry about forest fires and the CO_2 emitted as a result of those forest fires, and the CO_2 stored by the trees as natural sink can be used by the developed countries as their CO_2 count while the timber and the forest products can be used by the developing nation for further development.

4. Implementation of the 2nd Commitment Period of the Kyoto Protocol.

With the establishment of the above mentioned two technologies, emission trading (cap and trade) between the countries will be promoted to a greater extent and this also would be a very big step in solving the problem that the world environment is facing now. Currently various researches are going on in the Siberian forests of Russia and a case study for the improvement of the monitoring technique of forest fires and the calculation of the CO_2 emitted from forest fires through the model can be conducted there and if proven successful can be applied by the other nations under the Kyoto Protocol. And finally by taking these steps, the second commitment period can be implemented by all the nations. Figure 2 is a proposal system from this paper.

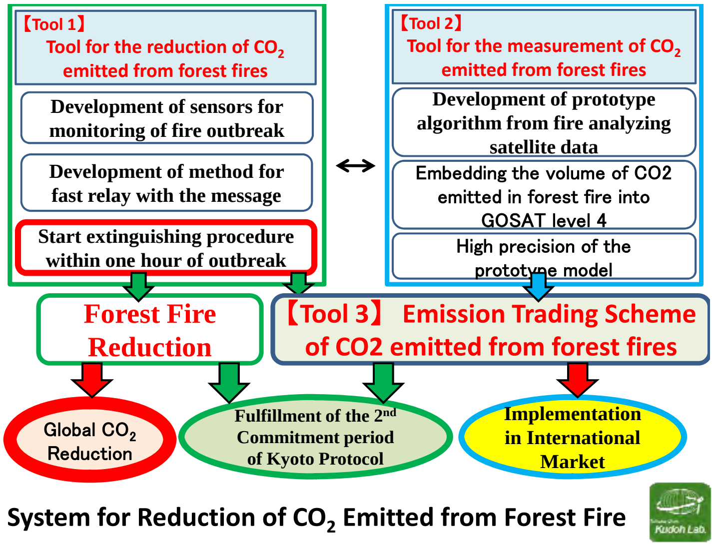

Fig. 2. Proposal system.

5. Case Study

Russia constitutes of about 20% of the total forest area in the globe and emits around one billion tons of CO_2 every year, so the effect of reduction of forest fires in Russia is huge. For that purpose, case study with should be implemented in Siberia with coalition of Japanese and Russian government with the collaborative research with the Russian Academy of Science being the base. We are considering the project scheme for the case study as shown in Fig.3.

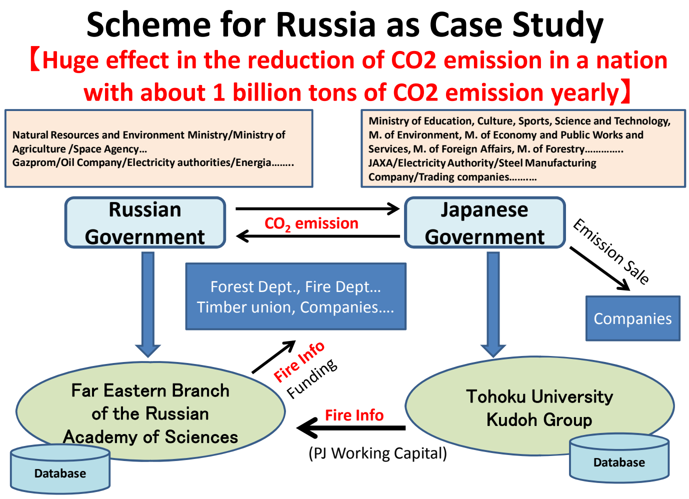

Fig. 3. Considering scheme of the project.

6. Conclusion

This study, if implemented, is certain to reduce the total emitted global CO_2 and can work as a trump card to solve the environmental problem that the world is facing by a mutual understanding and involvement of all the developing, emerging and developed nations.

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Error Correction of Watershed Map for Forest Functions Classification

유역단위 산림기능구분을 위한 유역구분도 오류 보정

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Abstract

Forests provide various socio-economic functions, based on the differentiated needs of the human. It is essential that the functions of forests should be identified and evaluated in order to meet social needs. The aim of this study was to correct error in watershed using two methods, and to compare the results. Methods were Simple Merge (SM) and Topology using Gaps (TG). The results showed that SM was simpler and more applicable, but there were stair shape watersheds. Although TG was showed smoother watersheds, total count of watershed was less than SM and it generated errors such as sliver polygon. Thus, we suggested SM was adequate for forest functions classification map.

요약

산림은 목재, 임산물 생산 등의 경제적 기능과 산지재해방지, 수원함양, 산림휴양 등 다양한 사회 생태적 기능을 제공하고 있다. 산림이 지니고 있는 다양한 기능을 객관적으로 평가하고, 정확히 파악하여 산림의 기능을 극대화하고 산림자원에 대한 사회적 수요를 충족시키기 위해서는 산림기능평가와 같은 객관적 평가가 필요하다. 이 연구는 유역단위의 산림기능구분도의 기초자료인 유역구분도가 내재하고 있는 오류들을 단순병합 방법과 토폴로지 방법을 이용하여 오류를 보정하고자 하였다. 연구결과, 단순병합방법은 간단하고, 적용하기 용이하였지만, 계단형 유역이 나타났다. 반면, 토폴로지 방법은 자연스러운 곡선형태의 유역형태가 나타나고, 불필요한 유역들이 줄어듦에 따라 총 유역 개수도 단순병합방법에 비해 적었지만, 슬리버폴리곤을 만드는 경우가 나타났다. 따라서 단순병합방법에 의한 유역구분도 보정방법이 적절한 것으로 판단된다.

서론 (Introduction)

산림은 목재, 임산물 생산 등의 경제적 기능과 산지재해방지, 수원함양, 산림휴양 등 다양한 사회 생태적 기능을 제공하고 있다. 산림이 지니는 다양한 기능을 정확히 파악하여 산림의 기능을 극대화하고 산림자원에 대한 사회적 수요를 충족시키기 위해서는 산림기능평가와 같은 객관적 평가가 필요하며, 수많은 공간자료가 사용되므로 GIS를 기반으로 분석하고 있다. 국유림과 공유림에 대한 산림기능구분이 완료되었으므로 사유림에 대한 산림기능구분도 제작이 요구되고 있다. 우리나라의 사유림은 대부분 소규모이므로 유역단위의 집단화된 산림기능구분이 적합하다. 그러나 DEM자료를 기반으로 제작된 유역구분도는 직선형 오류 및 슬리버폴리곤 형태의 오류를 내재하고 있으므로 유역구분도의 오류 수정은 산림기능구분도 제작의 필수적인 과정이다. 이 연구는 사유림의 산림기능구분도 작성을 위해 유역구분도의 오류를 제거하기 위한 해결방안을 모색하는데 그 목적이 있다.

재료 및 방법 (Methodology)

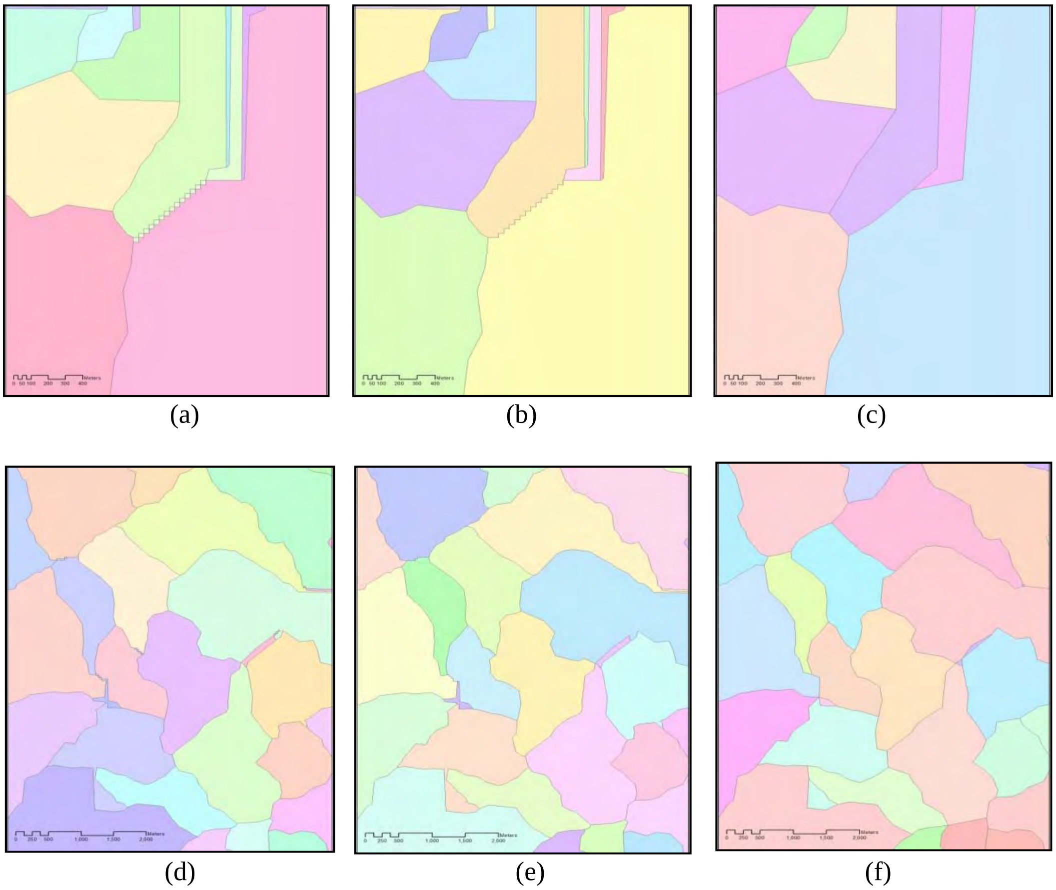
경상남도의 산림면적은 707,103ha로써 전국 산림의 약 11.1%를 차지하고 있다. 유역구분도의 오류 보정을 위한 접근방법으로 단순제거 및 병합과 토폴로지 방법을 사용하였다. 단순제거 및 병합방법은 일정면적 이하의 유역을 주변 유역에 병합하는 방법으로써 주변에 있는 유역 중 면적이 가장 크거나 경계가 가장 많이 접하고 있는 유역에 편입시킴으로써 오류를 제거하는 방법이다. 반면 토폴로지(topology, 위상)는 지리적 개체들 사이의 인접성, 연결성 및 포함에 대한 공간적 관계를 의미하고, 토폴로지 정리는 유효성 검사를 통해 위배되는 규칙을 확인하고 수정하는 과정을 가리킨다. 이 연구에서 토폴로지 방법은 일정면적 이하의 유역을 인위적인 GAP(규칙 위배)을 생성하고, 토폴로지 규칙 중 ‘must not have gaps’하여 토폴로지를 정리하는 방법을 사용하였다. 유역구분도를 검토한 결과, 1ha 미만의 유역에서 일반적으로 오류가 많이 발생함에 따라 오류 보정작업을 수행하였다.

결과 및 고찰 (Results and discussion)

연구 결과, 단순병합방법은 적용하기 쉽고, 유역구분도의 변형이 없다는 장점이 있다. 그러나 유역구분도의 정사각형 유역이 계단형으로 변형되는 것

으로 나타났다. 반면, 토폴로지를 이용한 인위적인 갭 생성 방법은 단순제거 및 병합방법에 비해 자연스러운 유역형태가 나타나고, 정사각형 유역이 자연스러운 직선형태로 나타나는 장점이 있다. 그러나 인위적인 갭을 제거하기 위해서는 적절한 범위(tolerance)를 설정해주어야 하며, 설정된 그 범위 때문에 오히려 슬리버폴리곤이 생성하거나 인위적인 갭을 제거하지 못하여 오히려 자료의 무결성을 저하시키는 것으로 나타났다. 또한 산림기능구분도의 축적이 1:25,000임을 감안할 때, 단순병합방법이 적절할 것으로 판단된다.

그러나 위의 두 방법에서 시스템적으로 규정할 수 없는 오류에 대해서는 육안검수 작업이 필요하다. 위의 방법의 적용은 산림기능구분 뿐만 아니라 유역단위의 분석 시 유역구분도 오류를 보정하기 위한 방안 모색에 의미가 있다.



(a) (b) (c)

(d) (e) (f)

Figure 1. Comparison by methods; (a) , (d) : raw data, (b), (e) : simple merge, (c), (f) : topology using gaps

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Abundance of butterflies in new grassland formed by forest fire and in forest

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Abstract

Forest fire is an important variable in forest ecosystem succession and is a dominant large scale disturbance factor. We investigated butterfly in grassland formed by forest fire, secondary forest, and primary forest, to estimate the impacts of forest fire in ecosystem. Butterfly was counted using the line transect method once a month from April to September for three years 2007 to 2009. Butterfly habitats were determined based on their larval habitats and classified as either forest inside (FI), forest edge (FE), or grassland (GL). The survival strategy of butterfly based on the numbers of voltinism and food plants was classified into two groups: specialist and generalist. A total of 93 species and 1,833 butterflies were observed in three habitats. Grassland (G) with 56 species and 572 individuals, secondary forest (F) with 57 species and 585 individuals and primary forest (Fp) with 51 species and 676 individuals were observed, respectively. Number of species and individuals of butterflies (G, F, Fp) in the three habitats were different according to habitat types. Survival strategy was also different among habitats. The pattern between number of species and individuals was different. It is thought that species composition of butterfly is similar from early stage of succession to secondary forest due to good movement ability and is not greatly affected by habitat destruction caused by forest fire. In contrast, abundance was obviously different between three sites. It is likely that difference of abundance relate to habitat reduction caused by forest fire. In primary forest, specialists and tree-feeding species increased.

요약

산불은 산림천이과정에 중요한 역할을 하고, 중요한 교란요인이다. 우리는 산불에 의해 형성되 초지, 이차림, 일차림에서 생태계에 미치는 나비의 영향을 파악하기 위해 조사하였다. 나비는 선조사법으로 조사하였고, 2007년부터 2009년 3년 동안 월 1회 조사하였다. 유충의 서식처에 따라 산림, 임연부, 초지의 3가지로 구분하였다. 나비의 생존전략은 발생회수, 먹이식물의 수에 의해 specialist와 generalist로 구분하였다. 총 93종 1,833개체가 관찰되었고, 초지에서 56종 572개체, 이차림에서 57종 585개체, 일차림에서 51개체, 676개체가 발견되었다. 나비의 종수와 개체수는 서식처에 따라 달랐으며, 생존전략 역시 달랐다. 초지와 이차림 사이에 종구성이 별로 달라지지 않았는데 이는 높은 이동성 때문으로 사료된다. 일차림에서는 specialists와 나무를 먹는 종의 비율이 높았다.

Introduction

Forest damages caused by various disturbances have increased due to climate change. Since 2000, typhoons with strong winds and heavy rain caused frequent occurrence of landslide and induced increase of tree mortality. In 2009, hundreds of thousands of pine trees in southern region of Korea withered in the drought in winter season. The dry spring has been increasing occurrence of forest fire. The gap in forest created by disturbance develops herbs and shrubs instead of trees. Such change of forest structure and vegetation may change fauna in forest.

Many studies on the diversity of butterflies have been conducted in various types of forest. However, little is known about how butterflies respond to change of forest structure and vegetation caused by forest fires. After forest fire, trees were destructed and herbs and shrubs grow afterwards in forest fire areas. In this process we expect that species that favor grassland increases while forest species decreases. However, as forest recovers, the situation will be again recovered with increasing of forest species. Similarly just after forest fire, the number of generalist that adopt in broad habitats and fast fliers will increase. However, as forest grows, we expect that the number of specialists that require rather limited habitat increases whereas the generalist decreases. We posed a hypothesis that the butterfly fauna will be changed after forest fire and succession. To test this, we surveyed the butterfly fauna in three different sites in grassland, secondary forest and primary forest.

This study addresses the following questions. Did the herb and shrub feeding butterflies increase after forest fire? Did the generalist common in forest fire area and specialist recover as forest grows?

Materials and Methods

Study sites

We selected three different types of habitats to compare butterfly fauna: grassland (G), secondary forest (F) and primary forest (Fp). Grassland sites, located in Mt. Hyunjongsan, Uljin, were changed from pine dominated forest into grassland by severe forest fires in 2000 and 2007. Secondary forest sites, Gilgok-ri, Uljin were covered with about 30 year-old pine (*Pinus densiflora*) trees. Primary forest sites, located in Gwangneung, were covered with 100-300 year-old deciduous trees with *Quercus serrata* Thub. Ex. Murray and *Carpinus laxiflora* (Siebold and Zucc) Blume.

Butterfly monitoring

The abundances of butterfly species were counted using the line transect method described by Pollard and Yates (1993) or/and Yamamoto (1975). All surveys were conducted on cloudless days and began at 10:00-14:00. The survey was conducted by steadily walking along the study routes at a speed of approximately 2 km/hour, and then recording butterflies observed within a width of 10 m along the routes. When identification of the species by sight was difficult, the butterflies were caught by net, identified and then released. We conducted the survey once a month from April to September for three years 2007 to 2009.

Classification of habitat and butterflies

Butterfly habitats were determined based on their larval habitats and classified as either forest inside (FI), forest edge (FE), or grassland (GL). If a species occupied more than one habitat, their habitat was considered to be the one that was more frequently utilized. The habitats of each species were primarily determined using SS Kim’s personal observations over approximately twenty years with the supportive data from Fukuda et al. (1982-1984).

The survival strategy of butterfly was followed by Kitahara and Fujii (1997). They classified the butterflies based on the numbers of voltinism and food plants:

specialist species are uni- or bivoltine and the number of food plant is less than 10 in one plant family, while generalist species are multivoltine and more than 10 food plant species in more than two families. However our limited information on food plants of butterfly species in Korea, we only considered the number of plant families for the classification excluding the number of food plant species. In the present study we categorized specialist species as uni- or bivoltine and limited in one families of food plant and generalist species as multivoltine and more than two families in food plants.

Analysis

We analyzed the relationship between variables using log-linear models for multidimensional contingency tables (Zar, 1997). The relationship between habitat and survival strategy was analyzed using number of species. The relationship between habitat (FI, FE, GL) and surveyed sites (G, F, Fp) were analyzed using number of species and individuals. Differences among surveyed sites, (1) G (grassland, Uljin) and F (secondary forest, Uljin), (2) G and Fp (primary forest, Gwangneung), (3) F and Fp, (4) G, F and Fp, respectively were analyzed with habitat types. Each analysis was carried out separately in three years and pooled three years. All statistical analyses were using Statistica ver 6.1.

Results

A total of 93 species and 1,833 butterflies were observed in three habitats in three years. Grassland (G) with 56 species and 572 individuals, secondary forest (F) with 57 species and 585 individuals and primary forest (Fp) with 51 species and 676 individuals were observed, respectively.

In 2007 when forest fire broken out, the number of butterfly species in G with 29 species and 137 individuals was lower than that of F was 34 species and 184 individuals. However in 2008, the number of butterflies was increased in grassland (G) with 46 species and 276 individuals while secondary forest (F) had 45 species and 217 individuals. In 2008, the number of individuals was highest in all three surveyed sites (Fig. 1).

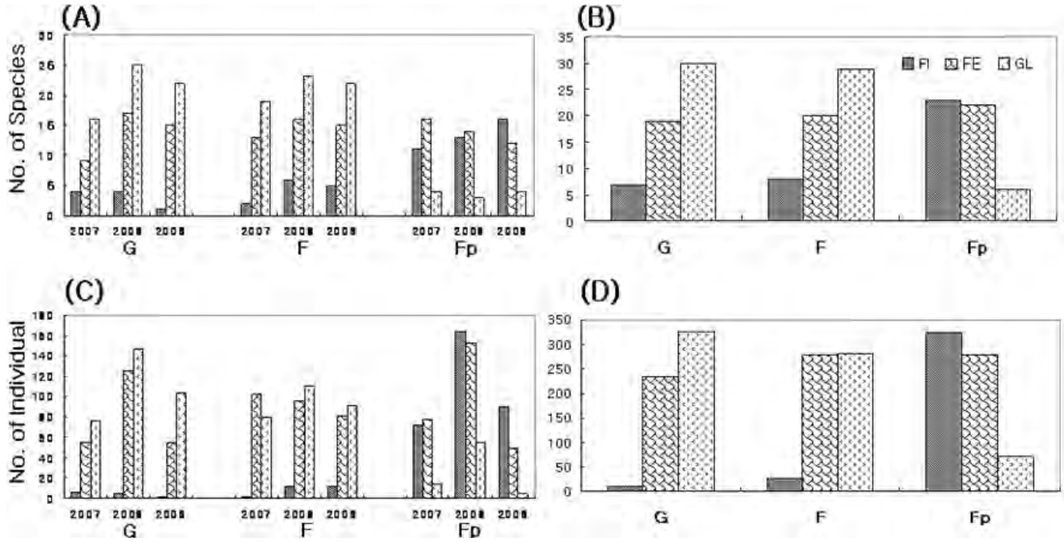

Figure 1. Occurrence of butterfly species according to the habitat types. (A) annual occurrence in number of species, (B) pooled occurrence in number of species, (C) annual occurrence in number of individuals, and (D) pooled occurrence in number of individuals. G: grassland after forest fire in Uljin, F: pine forest in Uljin, and Fp: primary forest in Gwangneung.

Among 93 species identified in the present study, GL species (37 species) was the largest in number, followed by FI (28 species) and FE (28 species). According to the survival strategy, 10 species were classified into generalist and 31 species were into specialist. Here we excluded the species in the analysis that we cannot classify. It was shown that butterfly habitat and survival strategy were not independent. Eleven species of FI were specialist, while four species of FE were generalist and 10 species were specialist. Among GL, six species were generalist and 10 species were specialist.

Survival strategy was also different among habitats. The pattern between number of species and individuals was different. In the number of species, specialist was larger than generalist in the three habitats. However, in the number of individuals large number of generalist and small number of specialist were observed in G and F (Fig. 2).

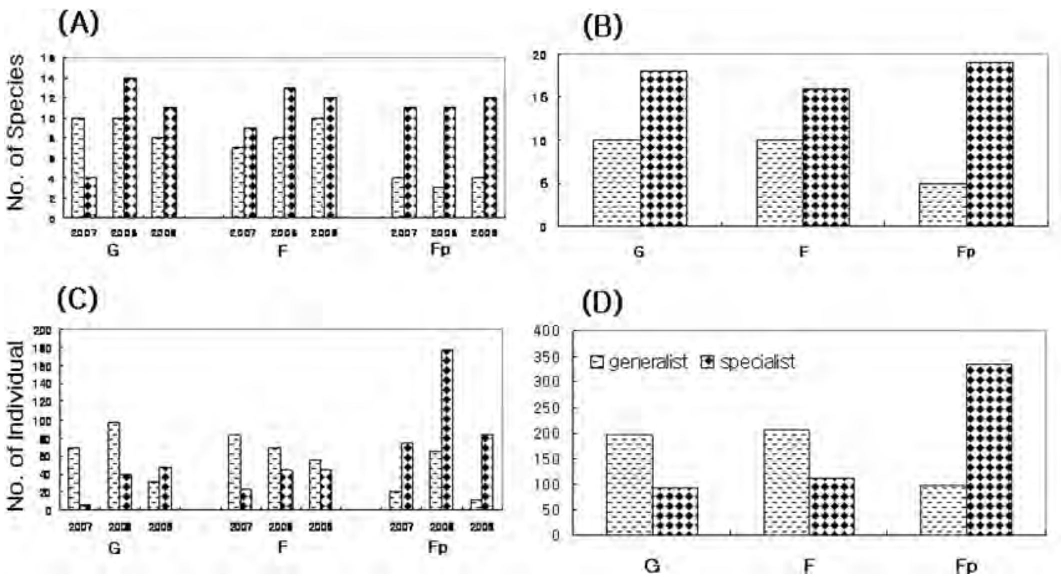

Figure 2. Occurrence of butterfly species according to the life strategies. (A) annual occurrence in number of species, (B) pooled occurrence in number of species, (C) annual occurrence in number of individuals, and (D) pooled occurrence in number of individuals. G: grassland after forest fire in Uljin, F: pine forest in Uljin, and Fp: primary forest in Gwangneung.

Discussion

We expected that assemblage structure of butterfly was changed according to change of forest structure and vegetation caused by forest fire. However, species composition of habitat and survival strategy of butterfly between grassland formed by forest fire and secondary forest was not different. But, species composition of primary forest site differed from one of two sites. It is thought that species composition of butterfly is similar from early stage of succession to secondary forest due to good movement ability and is not greatly affected by habitat destruction caused by forest fire. In contrast, abundance was obviously different between three sites. It is likely that difference of abundance relate to habitat reduction caused by forest fire. Given difference of butterfly in primary forest, many specialists, which have strong habitat preference, using trees as feeding plant is due to inhabiting, compared to grassland and secondary forest. This study suggests that species composition of butterfly is not affected by forest fire, whereas abundance is affected.

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Influences of disturbance intensity on diversity and abundance of arthropod predators (Araneae, Carabidae, Staphylinidae, and Formicidae) in fired-pine forest, Korea

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Abstract

Forest fires are one of the most important natural disturbances in forest ecosystem. Recently, due to increase of mega forest fire caused by climate change, it needs to estimate impact of forest fire in ecosystem. Intensities of disturbance in the study sites were characterized as follows: 0 (no fire), 1 (weak fire), 2 (strong fire), 3 (strong fire, human disturbance). Arthropod predators (Araneae, Carabidae, Staphylinidae, and Formicidae) were collected using pitfall traps and compared. A total of 124,009 individuals belonging to 169 species were collected in 12 study sites. The species richness of arthropod predators collected were 124 species in Araneae, followed by Formicidae (18 species), Carabidae (16 species), and Staphlinidae (11 species). Formicidae was most abundant, representing 65% of total, followed by Araneae (28%), Staphlinidae (5%), and Carabidae (2%). For analysis, Arthropod predators were divided by guilds. Araneae was assigned into two groups: wandering spiders and web spiders. Carabidae and Formicidae were assigned into two groups: forest species and grassland species.. This study suggests that Formicidae is very suitable bioindicator for short term survey than Araneae, Staphlinidae, and Carabidae.

요약

산불은 산림생태계에서 가장 중요한 교란요인이다. 최근에 기후변화로 인한 대형산불이 증가함으로서, 산불이 산림생태계에 미치는 영향을 평가할 필요가 증가하고 있다. 조사지의 교란강도는 0(산불 미발생), 1(약한 산불), 3(강한 산불), 4(강한 산불, 인간의 교란)의 4단계로 구분하였다.절족동물중 포식자

인 거미류, 개미류, 딱정벌레류, 반날개류를 함정트랩으로 채집하여 비교하였다. 총 12개 조사지에서 169종 12400개체가 채집되었다. 종풍부도는 개미류가 124종, 개미류 18종, 딱정벌레과 16종, 반날개과 11종이었다. 풍부도는 개미류가 가장 높아 전체 개체수의 65%를 차지하였고, 거미류 28%, 반날개과 5%, 딱병벌레과 2%였다. 분석을 위하여, 포식자를 기능군으로 구분하였다. 거미류는 배회성과 조망성, 딱정벌레과와 개미류는 산림성과 초지성으로 나누었다. 본 조사결과 개미류가 단기성 조사에서는 거미류, 반날개과, 딱정벌레과에 비해 보다 적합한 환경지표생물이었다.

Introduction

Forest fire in forest ecosystem is one of the most important factors of natural disturbance. Fires cause serious disturbance of forest ecosystem and economic damage. Forest fire damages many species living in forest due to burning vegetation and litter, and changing soil component. For example, ground beetles were more abundant in unburned area than in burned area. Soil microarthropods were more affected by destruction of environment than direct damage caused by fire. However, change of species composition of the forest vegetation caused by fires increases biodiversity and habitat heterogeneity in forest. Some studies reported that forest fire positively affected species component. Moretti et al. (2004) found that species richness of ground beetles and spiders increased with fire frequency in the southern Alps. In addition, as disturbance intensity increased, abundance of detritivores decreased, but herbivores increased.

Recently, forest fires tend to increase following global climate change. After the mid-1990s, mega forest fires are occurring more often in Korea. Several countries such as Australia, America, Greece, and Russia were greatly damaged by mega forest fire. The study on impacts of climate change on fire activity ongoing in Canada since the late 1980s predicted the increase of the fire weather and fire seasons in 21C (Podur and Wotton, 2010) Therefore, it is important to estimate disturbance caused by forest fire.

Arthropod predators, such as Araneae, Carabidae, Staphylinidae, and Formicidae, have often been used as bioindicator for urbanization, fragmentation of forest, change of land use. Araneae depends on microclimate factors and physical structure of the habitat than species richness of vegetation. It was known that Araneae was affected by herb, litter, and soil layers after forest fire. Araneae assemblages showed significant difference according to vertical structure and spatial composition of a habitat because it was divided into wandering spider and web spider according to predation method. Carabidae was known that wingless large species in disturbed area disappeared faster than small species. In addition, Carabidae has strong habitat preference and some opportunistic species quickly colonize the disturbed area. Staphylinidae has clear systematic character and responds sensitively to change of environment. Furthermore, specie component of Staphylinidae differs according to forest maturity. Formicidae has been used as indicator of various disturbances such as forest, clear cutting, and land use. Advantage of Formicidae is not affect by seasonal change and has strong habitat preference. However, there is not comparison study of 4 taxa as bioindicators, which is more useful. Therefore, to do effective environment assessment, 4 taxa need to be compared.

Due to successful reforestation in Korea, combustibles such as litters, dead branches and woods have accumulated in forest. After mid-1990s, mega forest fires have been frequently occurring. In general, reforestation of burned forest has been applied for recovery of burned forests. However, after the mega fire in 2000, natural regeneration of vegetation was suggested for recovery of the burned areas. When traditional reforestation is carried out, dead trees and branches are logged and small trees and shrubs are removed prior to reforestation. From view of disturbance, the process of reforestation is additional disturbance. This study aims to evaluate which is better bioindicator according to disturbance intensity in forest. Arthropod predators (Araneae, Carabidae, Staphylinidae, and Formicidae) were compared among four disturbance intensities (no fire, weak fire, strong fire, and strong fire followed by reforestation) in three burned areas.

Materials and Methods

Study sites and disturbance degree

This study was carried out in three burned areas (Goseong, Gangneung, and Samcheok) in the north-eastern coast region of South Korea. A total of 12 study sites (4 study sites in each of 3 burned areas) were selected for this study. Disturbance intensity was characterized as one of four disturbance degrees (hereafter DD). DD of unburned pine forest was 0, and DD after a weak fire was 1. DD after a strong fire was 2, and DD after a strong fire followed by reforestation was 3.

Arthropods sampling

Arthropods were collected by pitfall traps of plastic cup (depth 6.3 cm, mouth diameter 8 cm, bottom diameter 6 cm). Twenty pitfall traps were buried at each study site for 10 d from late May 2005. The survey period is considered best for sampling of arthropods since arthropods are active and abundant in this high temperature and low rainfall season from late May to early June in Korea. For 10 days, each of 20 traps was placed 5 m apart from adjacent trap along two lines, which were parallel away about 10 m. Ethylene glycol was used as a preservative, and it filled one-third of each trap. Arthropod predators (Araneae, Carabidae, Staphylinidae, and Formicidae) were identified to species or morphospecies level using the taxonomic keys under a stereomicroscope. All the specimens were deposited in the Insect Specimen Storage Room of the Korea Forest Research Institute.

Guilds of arthropod predators

Arthropod predators, Araneae, Carabidae, Staphylinidae, and Formicidae, were used for analysis. Araneae was assigned into two groups: wandering spiders and web spiders. Carabidae and Formicidae were assigned into two groups: forest species and grassland species. However, Staphylinidae itself was used as one guild due to little information of lifecycle.

Statistical analyses

The number of arthropod individuals collected a trap was log transformed (ln N+1) to reduce variance and was used for analysis. Tukey-Kramer's HSD multiple comparison was used to find difference in species richness, abundance, and guild of arthropod predators according to DD. Correlation analysis between guilds of arthropod predators and environmental factors was performed.

Multidimensional scaling (MDS) based on the Sorensen distance measure was used for two-dimensional ordination of arthropod predators, guild, Araneae, Carabidae, Staphylinidae, and Formicidae. Multi-response permutation procedures (MRPP) of a nonparametric protocol for testing the null hypothesis of no differences among arthropod predators, guild, Araneae, Carabidae, Staphylinidae, and Formicidae according to disturbance degree (DD) were used. MDS ordination and MRPP were conducted using PC-ORD (ver. 5.17) (McCune and Mefford, 1999), and the other analyses were performed using STATISTICA (Statsoft 2004).

Results

A total of 124,009 individuals belonging to 169 species were collected in 12 study sites. The species richness of arthropod predators collected were 124 species in Araneae, followed by Formicidae (18 species), Carabidae (16 species), and Staphlinidae (11 species). Formicidae was most abundant, representing 65% of total, followed by Araneae (28%), Staphlinidae (5%), and Carabidae (2%). When arthropod predators analyzed were compared among the four disturbance degrees, specie richness and abundance of Araneae, Carabidae, Staphylinidae, and Formicidae did not show significant difference ($P > 0.05$, Fig 1).

Fig. 2 showed MDS ordination of Araneae, Carabidae, Staphylinidae, and Formicidae. MDS ordination explained 86% of variation of Araneae and Formicidae, followed by Carabidae (78%), and Staphylinidae (33%). However, only MRPP of Formicidae was statistically significant ($P = 0.038$).

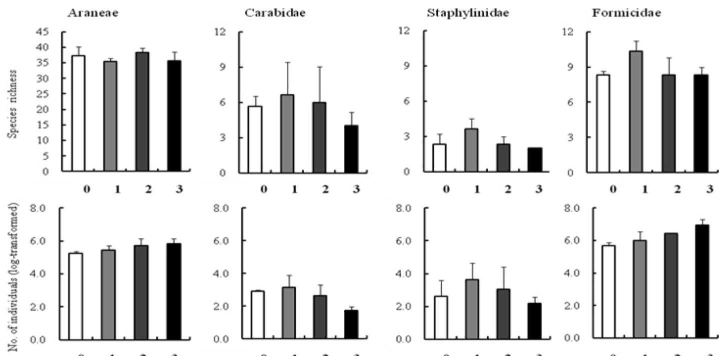

Figure 1. Species richness and number (ln N+1) of individual of arthropod predators (Araneae, Carabidae, Staphylinidae, and Formicidae) collected in pitfall traps in 4 different disturbance degrees. The bars indicate the SE.

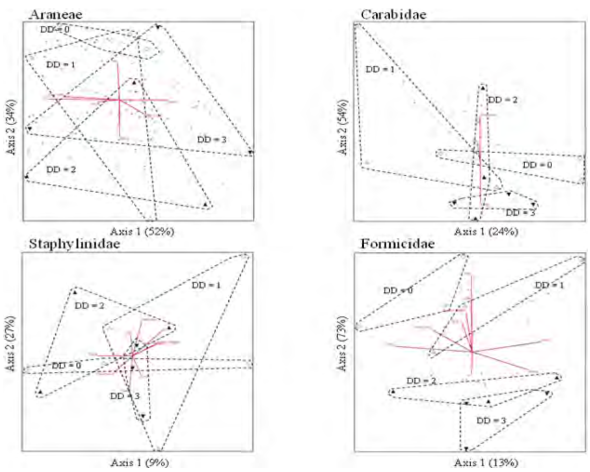

Figure 2. MDS ordination of arthropod predators (Araneae, Carabidae, Staphylinidae, and Formicidae) according to disturbance degree (DD). Circle: unburned site in pine forest (DD = 0), open triangle: site in pine forest burned by weak fire (DD = 1), dark triangle: site burned by strong fire (DD = 2), and reversed dark triangle: site burned by strong fire and reforested afterward (DD = 3). MDS ordination of arthropod predators (Araneae, Carabidae, Staphylinidae, and Formicidae) used only species collected at more than 2 sites.

Discussion

MDS ordination of arthropod predators explained above 78% of variation except for Staphylinidae. However, in only Formicidae, sites were located according to four disturbance degrees. Araneae and Carabidae were recognized as useful bioindicators in many studies such as forest fire, urbanization, fragmentation. However, they need to do long term survey due to change of species component according to seasonal change. In contrast, Formicidae does not change species component according to seasonal change and has strong habitat preference. This study therefore suggests that Formicidae is very suitable bioindicator for short term survey than Araneae, Staphlinidae, and Carabidae.

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Vegetation Type of *Pinus densiflora* stands and Damage Characteristics of Oak Stands in Post- forest fire Area in Korea

산불피해지 소나무 식생유형 및 참나무류 피해특성

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Abstract

This study was carried out to obtain basic database to manage damaged stands by forest fire by classifying vegetation type in pine forests and analyzing damage characteristics and sprout appearance in oak forests in Korea. Six vegetation units were surveyed in southern pine forest area of Gangwon where huge forest fires frequently occurred at. Vegetation communities were analyzed as five communities in pine stands such as *Quercus variabilis*e community, *Betula davurica* community, *Acer pseudosieboldianum* community, *Sasa borealis* community, and typical (*Pinus densiflora*) community and in cork oak communities there were two groups such as *Acer pseudosieboldianum* group and pure cork oak forest group. This study found that there were significant differences of stands growth and their quality caused by community characteristics in tree layer of pine forests and oak tree stands of *Quercus serrata Quercus mongolica*, etc. were dominant species in subtree layer of damaged stands. Considering damage characteristics of oak tree stands caused by forest fire, there were four types of aboveground survivals, partial-aboveground survivals, soil surface residuals, and soil surface loss, and as their damage types there were significant differences in occurrence and growth of sprouting. As considering stand structure and species composition, post-fire treatment for damaged stands needs to properly control the pine forest in dominant position for up level and manage sprouting of oak trees for low level.

요약

본 연구는 한국의 산불 피해지에서 소나무임분의 식생유형을 구분하고 참나무류의 피해 특성과 맹아 발생 특성을 분석하여 산불피해지의 임분관리를 위한 기초자료를 확립하고자 하였다. 대형 산불피해가 주로 발생하는 강원남부지역 소나무류는 6개의 식생단위로 나타났으며, 식생유형은 굴참나무군락, 물박달나무 군락, 당단풍나무군락, 조릿대군락, 전형군락 등 5개군락으로 구분되었으며, 굴참나무군락은 당단풍군과 전형군으로 구분되었다. 군락에 따라 임분의 생장 및 형질도 차이가 발생하고 있는 것으로 나타났으며, 아교목층 이하에는 졸참나무, 신갈나무 등 참나류가 우점하고 있는 것으로 나타났다. 산불피해지 참나무류 임분의 피해특성은 지상부생존형, 지상부 일부잔존형, 지제부잔존형, 지제부손실형 등 4가지 유형으로 나타났으며, 피해특성에 따라 맹아발생과 생장도 차이가 있는 것으로 나타났다. 따라서 산불피해지에서 임분관리는 상층 소나무와 하층에서 발생하는 참나무류의 맹아에 대한 지속적인 관리가 요구되었다.

Introduction

Gangwon-do area in Korea was continuously damaged by forest fire caused by site environmental characteristics. Once forest fire occurs at this area, it's easy to be an enormous disaster since this area consists of pine trees. As these pine forests are mostly consist of pure and artificial stands, they have high stand density and weak structure against forest fire. This study was investigated to obtain basic data for the purpose of post-fire survivor management by classifying vegetation type in pine forests and analyzing damage characteristics and sprout appearances in oak forests.

Methodology

Sample plots were selected at the eastern coastal area of Korea. Firstly, vegetation type in pine forests without forest fire damages was analyzed by using *Braun-Blanquet* method. Secondly, damage characteristics in post-fire pine forests and sprouts occurrence in post-fire oak stands were analyzed, respectively.

Results and Discussion

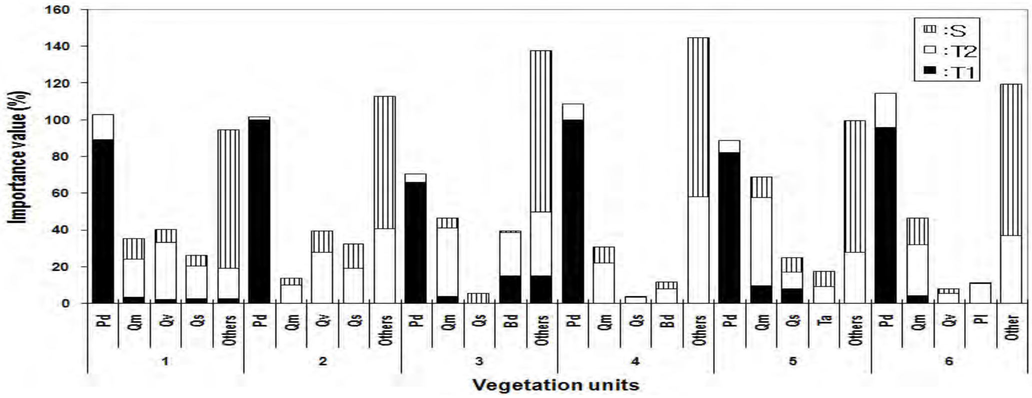

Figure 1. Species importance value by vegetation units in *Pinus densiflora* forests
(Pd : *Pinus densiflora,* Qm : *Quercus mongolica,* Qv : *Quercus variabilis,* Qs : *Quercus serrata,* Bd : *Betula davurica,* Ta : *Tilia amurensis,* Pl : *Prunus leveilleana*)

Table 1. Description of sprout decay of oak trees in burned and unburned forest area

Stand classification	Species	Degree of sprout decay (%)			
		Total	Severe	Moderate	Sound
Post-fire tree survival stands	*Q. variabilis*	100	18	23	59
	Q. mongolica	100	65	14	21
Non-fire stands	*Q. mongolica*	100	35	12	53

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Comparison of Difference between Gwangneung and Mt. Gumsan of Soil Respiration, Litterfall Production and Decomposing Litter in Natural Broad-leaved Forest

천연활엽수림에서의 토양호흡과 낙엽생산량 및 분해력의 지역간 차이 비교

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Abstract

This study was carried out to estimate annual soil respiration and litterfall production and to measure litter decomposition at the two LTER sites installed in a deciduous broadleaf natural forest in Gwangneung (central cool temperate forest) and Mt. Gumsan (transitional zone from southern cool temperate to warm temperate forest) where belong to different biome, South Korea.

We investigated the soil respiration for one year and measured litterfall production for two years, and measured decomposing litter for three years at the two LTER sites in Gwangneung and Mt. Gumsan. In the both two areas, soil respiration showed a clear seasonal variation, increased from April through July, peaked in August, and decreased thereafter. Also, seasonal trends of soil temperature were similar to soil respiration in the both two areas. These trends indicated a strong correlation between soil respiration and soil temperature. Annual soil respiration were 10.6 t CO_2 ha^{-1} for Gwangneung and 6.9 t CO_2 ha^{-1} for Mt. Gumsan, respectively. In the both two areas, litterfall production were significantly different among the sampling dates, whereas it was not significantly different between the years. The total annual mean litterfall production for two years were 5,934 kg/ha/yr for Gwangneung and 5,189 kg/ha/yr for Mt. Gumsan, respectively, and leaf litter accounted 63.2% for Gwangneung and 66.4% for Mt.

Gumsan, respectively. In the both areas, the leaf litter quantities were highest in *Quercus serrata*, followed by *Carpinus laxiflora* and *C. cordata*, etc., which are dominant tree species in the site. In the both two areas, the mass loss from the decomposition of leaf litter were fastest in *C. cordata*, followed by *C. laxiflora* and *Q. serrata*. 100% of litter for *C. cordata*, 98.7% for *C. laxiflora*, 85.3% for *Q. serrata* decomposed for 1,217 days in Gwangneung, while 84.1% of litter for *C. cordata*, 82.4% for *C. laxiflora*, 65.4% for *Q. serrata* decomposed for 1,070 days in Mt. Gumsan.

Introduction

Soils are the largest carbon pool in terrestrial ecosystems, containing m ore than two-thirds of total carbon in the terrestrial ecosystems. Soil respirati on (belowground respiration) is the major pathway of carbon transfer from so il to atmosphere, and a tiny amount of change in soil respiration rate may h ave profound impact on the atmospheric CO_2 budget, thus understanding soil respiration is crucial for the carbon balance of terrestrial ecosystems and for the global carbon balance (Ewel *et al.*, 1987; Son *et al.*, 2004). Litterfall inputs and litter decomposition represent a large and dynamic portion of the nutrient cycling in a forest ecosystem (You *et al*., 2000). In addition, the turnover of litter is a major pathway of the nutrient and carbon inputs to forest soils. Significant amounts of organic matter and nutrients in the soils can be transferred during litter decomposition processes (Lisanework and Michelsen, 1994).

Natural hardwood stands in the temperate forest zone and warm temperate forest zone of the Korea are mixed with various kinds of deciduous tree species (Kim *et al*. 2003). Although several studies have reported soil respiration, litterfall inputs and litter decomposition in hardwood forest ecosystem in Korea (Kim *et al*., 1997; Kim *et al*., 2003; Koo, 2006), little is known about the direction and rates of change associated with mixed-hardwood forest ecosystem. The objectives of this study were 1) to estimate annual soil respiration, 2) to measure litterfall and nutrient quality; 3) to examine decomposition rates in *Quercus serrata, Carpinus laxiflora* and *C. cordata* litter at the LTER sites in Gwangneung and Mt. Gumsan deciduous broad-leaved forest in Korea.

Methodology

This study was conducted in the two broadleaf deciduous forest in Gwangneung, Gyeonggi-do, and in Mt. Gumsan, Gyeongnam-do, South Korea. These areas had been registered as an official LTER sites since 1998 and an official KoFlux site since 2002 (Kim *et al*. 2003). Gwangneung forest (37°44'45.7″ N, 127°09'01.0″ E) was located in the central part of the cool-temperate forest zone in Korea, and the soils were classified as brown forest soils developed on granite gneiss. Annual precipitation in the site averages 1,365mm and annual mean temperature is 11.3℃. Major tree species are composed of *Quercus serrata, Carpinus laxiflora*, *C. cordata, Sorbus alnifolia*, *Celtis jessoensis* (Lim *et al*. 2003). Mt. Geumsan forest (34°45'41.4″ N, 127°59'12.9″ E) was located in the southern coastal area and belongs to warm temperate forest zone in Korea and the soils were classified as brown forest soils developed on granite gneiss. Annual mean temperature reaches 10.8℃ and annual precipitation is about 1394mm. Major tree species are composed of *Quercus serrata, Chamaecyparis obtusa, Styrax japonica, Acer pseudo-sieboldianum*, *Carpinus tschonoskii*, *Stewertia pseudo-camellia*.

Soil respiration was measured using an infrared gas analyzer (EGM-4, PP System Inc., UK) connected to a SRC-1 chamber (100mm inside diameter) from April through October 2007. The chamber was gently inserted into a forest floor to a depth of less than 0.5cm, without the use of previously installed collars. Since insertion may cause a burst of CO_2 from the soil, measurements did not begin until a few minutes had elapsed from the placement of the chamber. Five randomly selected sample points were measured in each plot. Soil temperature was measured with a soil temperature probe (PP Systems Inc.) at 15cm depth, and soil moisture was measured gravimetrically adjacent to the chamber.

Litterfall was collected in circular traps devised by Hughes *et al*. (1987) using 1.5mm nylon net. The collecting area was 0.25m^2. Twelve traps in three plots (20×20m) were installed 50cm above ground. Litter was collected at approximately monthly intervals from October 2005 to September 2007. Litter collected from each trap was transported to the laboratory and oven-dried at 65℃ for 48 hours. All dried samples were separated into leaf, bark, flowers, acorn, woody and miscellaneous components, and each portion was weighed.

Mass loss and nutrient release in decomposing litter were estimated using the litterbag techniques employing 30×30cm nylon bags with a 1.5mm mesh size. Fresh leaf litter from the site was collected during the heavy litterfall season (late

November) in 2004. Collected litter samples were dried to constant mass at room temperature for 14 days and sorted into representative deciduous foliage in the stands. Ten grams of litter of air-dried three dominant four species (*Q. serrata*, *C. laxiflora*, and *C. cordata*) was weighed to the nearest 0.01g and places in numbered litterbags. Subsamples from each litter type were also taken to determine the oven-dried mass at 65℃ for 48 hours. The litterbags were randomly place on the forest floor on 24 December 2004. The thirty-six bags (3 plots × 4 species × 3 replication) in each sampling time were collected on six occasions over the study period. Collected bags were oven-dried at 65℃ for 48 hours. Litter in the bag was cleaned by gentle brushing with a soft paintbrush to remove mineral soil and weighed to determine litter mass loss rates. Litterfall and litter in the bag were ground in a Wiley mill to pass a 40-mesh stainless steel sieve. All nutrients (N, P, K, Ca, Mg) were analyzed by the standard method of the National Institute of Agriculture Science and Technology (1988).

Results and Discussion

Soil respiration

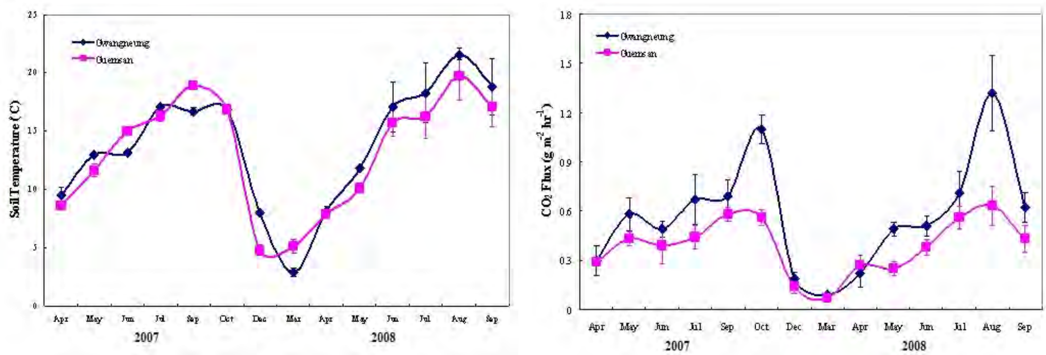

Fig. 1. Seasonal soil temperature (left), and soil respiration rate (right) for two years in Gwangneung and Guemsan forest.

Litterfall inputs

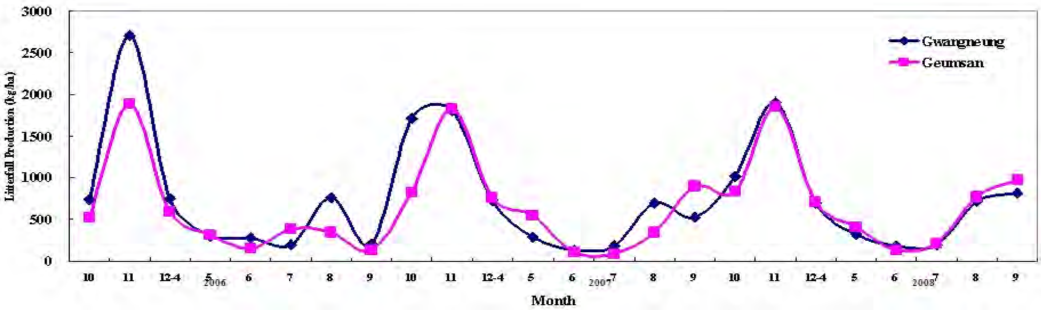

Fig. 2. Seasonal patterns of litterfall production for three years in Gwangneung and Guemsan forest.

Litterfall inputs

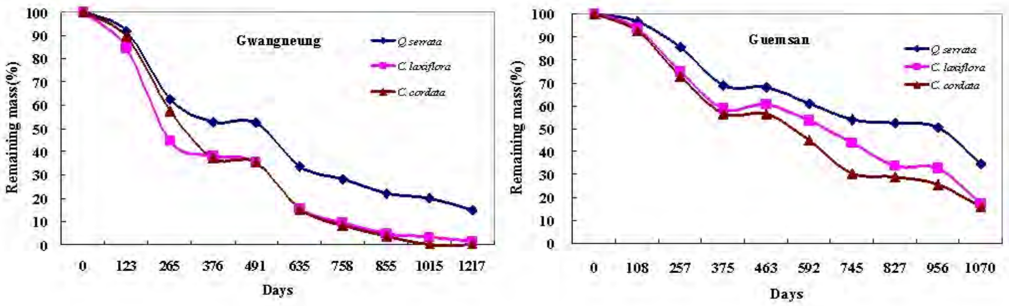

Fig. 3. Remaining mass of leaf litter for about three years in Gwangneung and Guemsan forest.

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Community fluctuation and Functional feeding groups of Benthic macroinvertebrates in Forest fire area of Samcheok

삼척 산불지의 저서성대형무척추동물 군집변동과 섭식기능군에 관한 연구

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Abstract

This study was conducted for searching the community structure, biological evaluation of water quality, community analysis and functional feeding groups (FFGs) of benthic macroinvertebrates in forest fire area of Samcheok.

요약

본 연구는 삼척 산불지역 계류에 서식하는 저서성대형무척추동물을 이용하여 산불 후, 이들 분류군의 군집구조, 생물학적 수질평가, 군집분석 및 섭식기능군을 분석하였다.

Introduction

Benthic macroinvertebrates are common inhabitants of lakes and streams where they are important in moving energy through food webs. The term "benthic" means "bottom-living", so these organisms usually inhabit bottom substrates for at least part of their life cycle; the prefix "macro" indicates that these organisms are retained by mesh sizes of ~200-500 mm (Rosenbergand Resh, 1993). Benthic macroinvertebrate species are differentially sensitive to many biotic and abiotic factors in their environment. Consequently, macroinvertebrate community structure has commonly been used as an indicator of the condition of an aquatic system (Armitage et al., 1983; Rosenberg and Resh, 1993). Biotic index systems have been developed which give numerical scores to specific "indicator" organisms at a particular taxonomic level (Armitage et al., 1983). Such organisms have specific requirements in terms of physical and chemical conditions. Changes in presence/absence, numbers, morphology, physiology or behaviour of these organisms can indicate that the physical and/or chemical conditions are outside their preferred limits (Rosenberg and Resh, 1993). Presence of numerous families of highly tolerant organisms usually indicates poor water quality (Hynes, 1998).

The most diverse group of freshwater benthic macroinvertebrates is the aquatic insects, which account for ~70% of known species of major groups of aquatic macroinvertebrates in Korea. Thus, as a highly diverse group, benthic macroinvertebrates are excellent candidates for studies of changes in biodiversity of forest fire area.

Methodology

1. Collection and Identification

Collecting method was done by qualitative and quantitative method. Larvae fixed with 70% Ethyl alcohol in the lab for two days and then preserved in 80% ethyl alcohol. All specimen which used in this study were preserved in animal taxonomic laboratory of Andong National University.

2. Community analysis

1) Dominance index(DI) $= (n_1+n_2)/N$

(N : Individual number, n1, n2 : Dominant and subdominant species individual number)

2) Diversity index(H\`) $= -\sum(n_i/N \cdot \log2 n_i/N)$

(n_i : i's individual number, N : Individual number)

3) Evenness index(E') $= H`/\log_2 S$

(H\` : Diversity index, S : Species number)

4) Richness index(RI) $= (S-1)/Ln(N)$

(S : Species number, N : Individual number)

5) Functional feeding group(FFG) and Community stability

Merritt-Cummins(1996) and Ro(2004)

6) Ecological score of benthic macroinvertebrate community(ESB) $= \sum (S_i \cdot Q_i)$

Q_i : Environmental quality score of individual taxa

S_i : Species frequency to i environmental quality

Results and Discussion

1. After the occurrence of forest fire, fluctuation in species and individuals investigated by year, 61 species, 3.045 individuals in 2006. And in 2007, 71 species, 3.645 individuals, in 2008, 58 species, 1,563 individuals.

2. After the occurrence of forest fire, dominance index showed the tendency to decreased every year. It showed that forest ecosystem restoration and valley ecosystem stabilization.

3. After the occurrence of forest fire, diversity index showed the tendency to increased and a high Qi score of species increased every year. And appearance ratio of biological indicator species was steadily increased.

4. As a result of functional feeding group by year, it showed a trend that individuals of GC type which is a functional group picking up and eating FPOM (fine particulate organic matter) from deposits in the bottom of water or benthic areas and performs an important function of material circulation in ecosystem decrease every year.

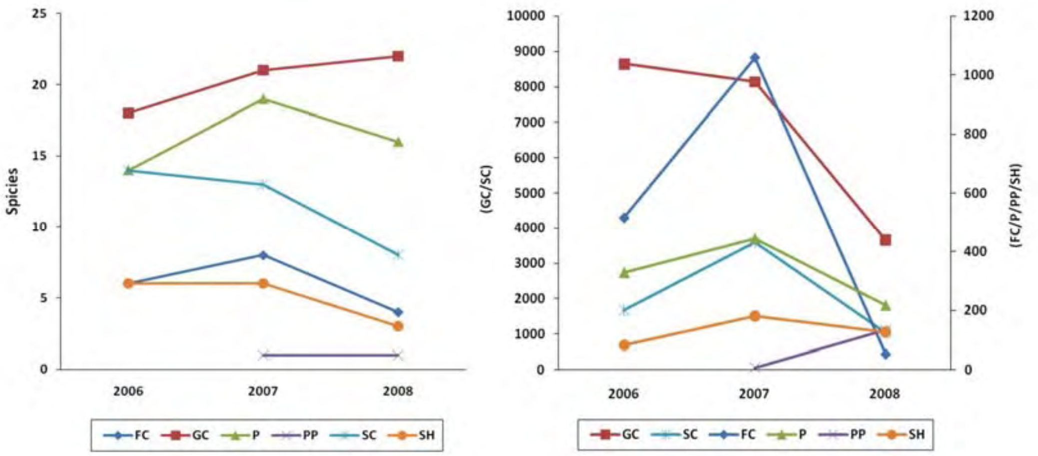

Fig. 1. Species and individual number of functional feeding groups of benthic macroinvertebrates at the surveyed sites .

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Community stability of Benthic macroinvertebrates in Forest fired area of Uljin

울진 산불지의 저서성대형무척추동물의 군집안정성 분석

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Abstract

This study is to provide basic data on the effects of the forest fire on the ecology and recovery aspects by performing analysis on the comparison of community analysis, functional feeding group and community stability by understanding benthic macroinvertebrate’s dispersion.

요약

본 연구는 울진 산불지역의 저서성대형무척추동물의 군집분석, 섭식기능군 및 군집안정성 분석을 통해 산불 후, 계류생태계의 복원 양상에 대해 연구하였다.

Introduction

Forest Fire has had tremendous effects on the ecological succession processes, allochemical characteristics of soil and water quality of the nearby ecology and animals such as benthic macroinvertbrates.

Benthic macroinvertbrates are river creatures that have variety of species. These creatures have a very small migratory pattern. It is easy to collect these specimens, and they are used in various ecological studies. Especially, aquatic insects utilize various food resources in fresh water ecology. Therefore, functional feeding group's classification is suggested according to the food utilization characteristics. Water environment can be diagnosed based on the functional feeding group's make up. Therefore, to understand drastic changes in the mountainous species ecology due to the forest fires and to understand recovery processes, continuous and systematic investigation must be done on the recovery pattern and aspect of the ecosystem by monitoring composition of species, H', RI, Dominant species and community fluctuation of the benthic macroinvertbrates which has excellent adaptability according to the different habitat and of the special water environment.

Methodology

1. Collection and Identification

Collecting method was done by qualitative and quantitative method. Larvae fixed with 70% Ethyl alcohol in the lab for two days and then preserved in 80% ethyl alcohol. All specimen which used in this study were preserved in animal taxonomic laboratory of Andong National University.

2. Community analysis

1) Dominance index(DI) $= (n_1+n_2)/N$

(N : Individual number, n1, n2 : Dominant and subdominant species individual number)

2) Diversity index(H\`) $= -\sum(n_i/N \cdot \log 2 n_i/N)$

(n_i : i's individual number, N : Individual number)

3) Evenness index(E') $= H\text{\`}/\log_2 S$

(H\` : Diversity index, S : Species number)

4) Richness index(RI) $= (S-1)/\mathrm{Ln}(N)$

(S : Species number, N : Individual number)

5) Functional feeding group(FFG) and Community stability

Merritt-Cummins(1996) and Ro(2004)

6) Ecological score of benthic macroinvertebrate community(ESB) $= \sum (S_i \cdot Q_i)$

Q_i : Environmental quality score of individual taxa

S_i : Species frequency to i environmental quality

Results and Discussion

1. As a result of examining an aspect of changes in species and individuals of E.P.T. taxa investigated in experimental area by year, Ephemeroptera was 21 species, 2434.6 inds./㎡, Plecoptera was 3 species, 199.8 inds./㎡, and Trichoptera 14 species, 540.2 inds./㎡in 2007. And in 2009, Ephemeroptera was 9 species, 296 inds./㎡, Trichoptera was 4 species, 44.4 inds./㎡, and Plecoptera was 0 species, showing that species and individuals belonging to E.P.T. taxa decrease rapidly every year.

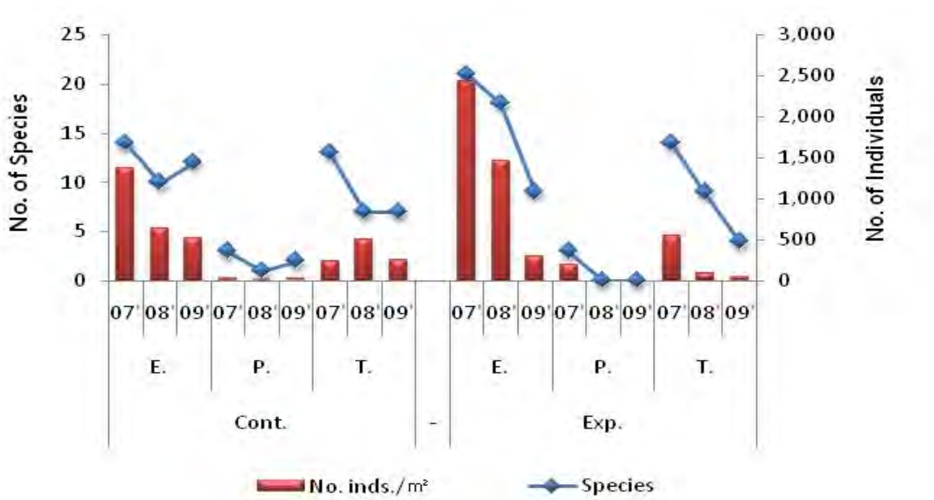

Fig. 1. Fluctuation of E.P.T. taxa of species and individuals number by year.

2. As a result of community analysis by year, in 2007 just after the occurrence of forest fire, it showed that H' and RI relatively high in experimental area compared with control area, but in 2008 when The water system started to be influenced by the fire directly, it showed a trend that H' and RI decreased in the experimental area.

3. As a result of functional feeding groups (FFGs) by year, it showed a trend that species and individuals of GC type which is a functional group picking up and eating FPOM (fine particulate organic material) from deposits in the bottom of water or benthic areas and performs an important function of material circulation in riparian ecosystem decrease every year.

4. As a result of community stability by year, there was no significant difference in community stability between the experimental water system and control water

system in 2007, but as an environment of water system in forest fire area started to be somewhat destroyed, from 2008, it is shown that both species in I area which have great ability of resistance and recovery and species in III area which live in relatively stable water system decreased a little.

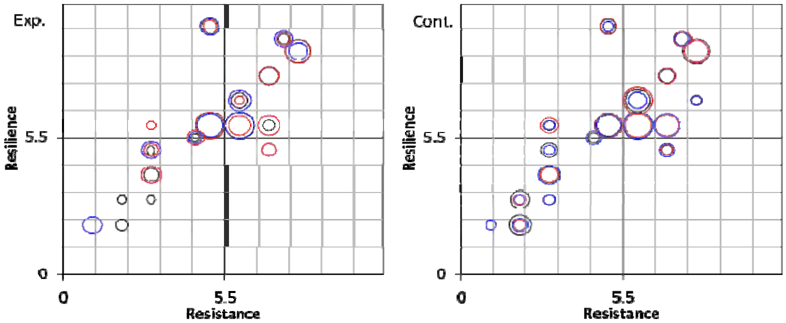

Fig. 2. Analysis of stability factors relative resistance and resilience in the control and experimental area (in each year). *Black : 2007, Red : 2008, Blue :2009

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Forest Fire Risk Mapping Based on Analytic Hierarchy Process

분석적 계층절차에 기반한 산불 위험도 지도화

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Abstract

Forest fires have adverse ecological, economic, and social impacts. In this light, the present research aimed to construct a fire risk model using a GIS-based multi-criteria analysis. Analytic Hierarchy Process (AHP) was applied, and the experimental results were obtained from Indian expert group (IEG). Moreover, producer's accuracy, user's accuracy, and overall accuracy were introduced in order to compensate for the limitations of the evaluation method that most researchers use. Statistical evaluations revealed that the approach of the IEG together with the equal interval thresholding method provided the fire risk mapping result: 94.25% overall accuracy. Therefore, this paper proposes a robust forest fire risk mapping strategy.

요약

산불은 생물적, 경제적, 그리고 경제적으로 상당한 영향을 미치고 있다. 이런 의미에서 본 연구는 GIS에 기반한 복수조건분석을 이용하여 산불위험도를 지도화하는데 그 목적을 두고 있다. 분석적 계층절차 방법이 적용되었으며 인도 산림전문가 그룹의 의견에 기반한 실험 결과가 획득되었다. 더구나, 기존

다수의 연구에서 사용되었던 정확도 평가방법의 한계를 극복하기 위하여 생산자 정확도, 사용자 정확도, 전체정확도가 사용되었다. 인도 산림전문가 그룹의 의견에 기반한 실험 결과를 평가한 결과 본 연구는 94.25%의 높은 전체정확도를 나타내었다. 이에 본 연구는 확고한 산불 위험도 지도화 전략을 제공하였다.

서론 (Introduction)

산불은 물리적, 생태적, 그리고 환경적으로 지대한 영향을 미치는 재난이다. 지속적인 화재의 발생은 숲의 손실을 발생시키는 주요 문제요소들 중의 하나이다. 산불을 막기 위해서 기존에는 화재감시타워나 수작업의 화재통제시스템을 운영하였다. 그러나, 이는 매우 비효율적이며 비용이 많이 소요된다. 이런 의미에서 산불 위험도 지도화는 효율적이고 실용적인 화재 모니터링 및 관리를 위해서 필수적인 요소로 등장하고 있다. 화재 위험 모델링은 화재에 영향을 미치는 다양한 요소들에 기반한 매우 복잡한 과정을 거친다. 그러나, 원격탐사자료와 지리정보시스템(GIS)을 이용하게 되면 보다 효과적으로 이 과정을 수행할 수 있게 된다. 본 연구의 목적은 다음과 같이 정리할 수 있다. 첫째, 지리정보시스템에 기반하여 화재 위험도 모델링을 수행한다. 둘째, 산림전문가의 의견에 기반하여 산불에 미치는 요소들의 점수화와 가중치 부여를 수행한다. 셋째, 기존 정확도 평가방법의 한계를 극복하는 다른 평가방법을 사용한다. 이를 통해 본 연구에서 제시한 산불 위험도 지도화 방법의 정확도와 신뢰도를 확인한다. 본 연구는 우선 아래의 절에서는 연구대상지에 대한 설명과 화재에 영향을 미치는 요소들, 그리고 이들을 이용하여 화재 위험도 모델링을 수행하는 구체적인 방법론에 대해 설명한다. 이후 획득된 결과를 분석하여 제시된 화재 위험도 지도화 방법이 신뢰할 만한 정확도를 보유하는지 확인한다. 최종적으로 본 연구를 통해 획득한 결과물들에 대해 결론에서 정리한다.

방법론 (Methodology)

대상지역은 인도의 Namakkal district of Tamil Nadu에 있는 Eastern Ghats 언덕이 선택되었다. 이 지역은 해발고도가 180미터부터 1415미터에 이르는 지역으로 그 면적으로 503 제곱 킬로미터에 달한다. 지면기울기는 평탄한 지역부터 40도에 이르는 지역까지 다양하다. 산불에 영향을 미치는 주요 다섯가지 요소들은 경사향, 경사도, 식생분포 및 밀도, 거주지 및 도로가 있다. 이들 요소들이 만드는 GIS 레이어를 이용하하여 산림 위험도를 지도화하기 위하여 다음과 같은 식 (1)을 이용하였다.

$$FRV = \sum_{i=1}^{5} W_i S_i \tag{1}$$

여기서 FRV는 화재 위험도, W_i 는 i번째 레이어의 가중치, S_i 는 i번째 레이어내의 카테고리의 화재 위험지수이다. 레이어의 가중치와 카테고리의 화재 위험지수를 정량화하기 위해서 분석적 계층절차 방법 (AHP)이 적용되었다. 이 분석적 계층절차 방법은 정량화 문제에 있어서 발생할 수 있는 주관성과 불일치성을 해결하는데 기여한다. 인도 산림전문가 15명을 대상으로 계층절차 방법을 적용하였으며 이를 통해 3명만이 이 방법을 통해 화재위험지수의 정량화에 있어서 객관성과 일치성을 보이는 것으로 분석되었다.

실험결과 및 분석 (Experimental Results and Analysis)

인도산림전문가의 의견을 바탕으로 지도화한 산불 위험도는 다음의 그림 1(좌)에서 보는 바와 같다. 그 위험도는 Very-high, High, Medium, Low, Very-low의 다섯단계로 구분하였다. Very-high는 전체면적의 5.87%, High는 52.31%, Medium은 30.13%, Low는 9.83%, 그리고 Very-low는 1.85%를 차지하였다.

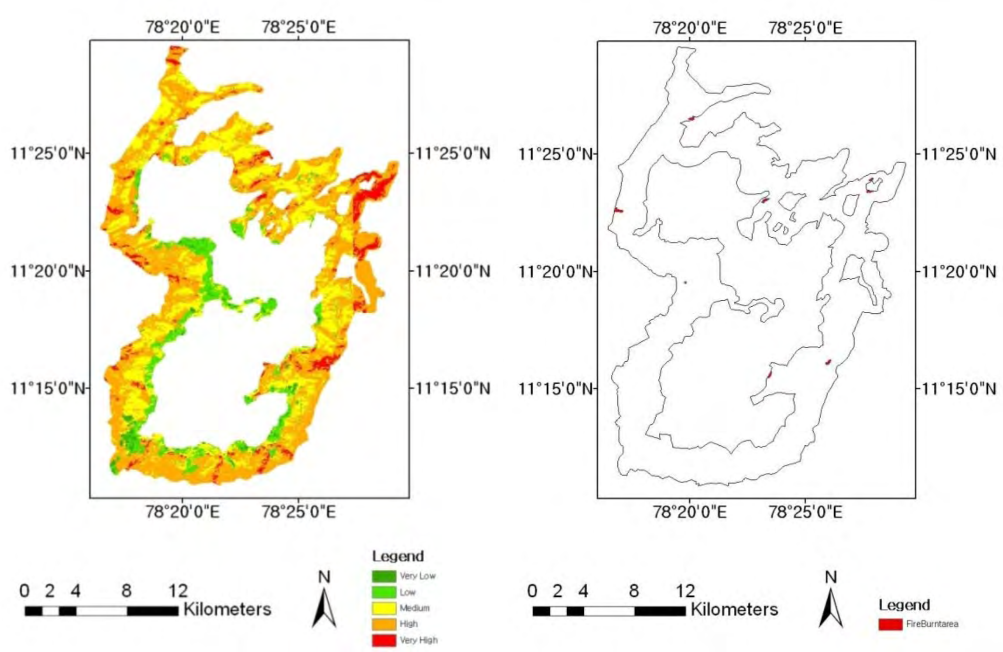

그림 1. 계산된 산불위험도 지도(좌)와 실제 산불발생 지도(우)

획득된 산불위험도 지도의 정확도를 평가하기 위해 실제 산불발생지도 (그림 1(우))와 정량작인 비교를 수행하였다. 산불에 가장 치명적인 very-high 위험지역만을 기준으로 아래의 표 1에서 보는 바와 같이 생산자 정확도, 사용자 정확도, 그리고 전체 정확도를 계산하였다. 전체정확도가 94.25%에 달하는 높은 정확도의 결과를 보여주고 있다.

표 1. 생산자 정확도, 사용자 정확도, 전체 정확도

생산자 정확도 (%)	사용자 정확도 (%)	전체 정확도 (%)
74.74	3.14	94.25

결론 (Conclusions)

본 연구는 지리정보시스템을 기반으로 하여 화재위험도를 모델링하였다. 특히, 산불 레이어들 사이의 상태적인 중요도 평가를 통하여 이를 수행하였다. 이의 평가를 위해 분석적 계층 절차방법이 도입되었다. 인도 타밀지역이 연구

대상지로 선정되었으며 인도 산림전문가들의 의견을 바탕으로 산불 위험도 지도화를 수행하였다. 정확도 평가 결과 전체정확도가 94.25%에 이르렀으며, 이는 본 연구를 통하여 신뢰도 높은 산불 위험도 지도화 방법을 제시하였음을 의미한다.

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Changes of Species Diversity on Moth Communities at Forest Fire Region in Samcheok, Korea

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Abstract

We investigated moth communities in Samcheok, Korea, to elucidate the influence of the East Coast Fire in 2000. Moths were collected with UV light traps 4 times a year from 2006 to 2009 at 3 sites: Unburned area (Site 1), Surface fire area (Site 2), and Crown fire area (Site 3) sites, respectively. A total of 3,804 individuals belonging to 727 species from 30 families were captured at the 3 study 1,727 individuals of 505 species (27 families) at Site 1, 1,193 individuals of 353 species (24 families) at Site 2, and 885 individuals of 340 species (25 families) at Site 3. Species richness and individuals of Noctuidae, Pyralidae, Geometridae, and Tortricidae were the highest at all 3 sites. All of species richness, individuals, and species diversity (*H'*) were the highest in Site 1 for 4 years. The index of similarity (α-Index) was higher between Site 2 and 3 in 2006, while higher between Site 1 and 2 in 2009. Moths were grouped into 16 categories by hosts of the larval stage. Individuals of moths of herbaceous feeding habit continuously decreased at Site 3, but proportion of individuals of tree feeding habits continuously increased. The present results showed that moth communities was relatively recovered according to vegetation change after forest fire and regeneration of moth communities in surface fire area was more faster than in crown fire area.

요약

2000년 동해산불의 영향을 파악하기 위해 삼척에서 나방군집을 조사하였다. 나방은 적외선등을 이용하여 3개 조사지에서 2006년부터 2009년 사이에 연 4회 조사를 하였다. 총 30과 727종 3804개체가 채집되었는데, 1조사지에서 27과 505종 1727개체, 2조사지에서 24과 353종 1193개체가 채집되었다. 종수와 개체수가 많았던 과는 Noctuidae, Pyralidae, Geometridae, Tortricidae 였다. 종수, 개체수, 종다양도는 조사지 1에서 가장 높았다. 유사도지수는 2006년에 조사지 2와 3조사지 사이와 2009년의 조사지1과 2 사이에 높았다. 나방류를 유충의 먹이식물에 따라 16개 종류로 구분하였다. 초본을 먹은 나방의 개체수는 조사지3에서 지속적으로 감소한데 비해, 나무를 먹는 종은 증가하였다. 산불후 식생이 회복됨에 따라 나방군집도 회복되며, 지표화 피해지에서 회복속도가 빠른 것으로 나타났다.

Introduction

Forest fire is one of major disturbance in forest ecosystem and determines landscape pattern due to creating various habitat in forest. However, forest fire causes physical, chemical, and biological change such as decrease of biomass, surface runoff according to soil erosion, and decline of water storage function. In Korea, mega forest fires occur intensively in the east coast region. In April 2000, mega forest fire burned 23,794 ha including Goseong, Gangneung, Samcheok, and Uljin, and was recorded by the largest fire in Korea. Vegetation in burned area in east coast region is recovering quickly. However, except for birds, little is known about how wildlife responds to vegetation recovery. Moths have abundant species richness and play important role such as herbivore, pollinator, and feed resource of small animals in forest ecosystem. Moths are useful bioindicator to estimate forest environment due to various feeding habit, such as evergreen tree, deciduous tree, lichen, moss, mushroom, etc., in larval stage.

In this study, we investigated moth communities at unburned area, surface fire area, and crown fire area in Samcheok, Korea, to elucidate the influence of the East Coast Fire in 2000. In addition, change of moth communities was analyzed using feeding habit of larval stage of species collected.

Materials and Methods

In Samcheok damaged by East coast fire, moths were collected with UV light traps 4 times a year from 2006 to 2009 at 3 sites: Unburned area (Site 1), Surface fire area (Site 2), and Crown fire area (Site 3) sites, respectively. Moths were collected with UV light traps (Bioquip, U.S.A). Each traps consisted of a 22-W UV light of O type, powered by 12 V DC batteries. Moth sampling was conducted for 3 hours after dusk, avoiding the rainy day and the full moon day. Moths were identified at the species level when possible, based on available taxonomic keys and literature. When moths could not be identified on appearance, it was identified after dissection of genitalia. All material is now deposited in the Insect Specimen Storage Room of division of life sciences, college of natural sciences, university of Incheon, Korea.

Analysis

Community indices

We calculated species diversity by the Shannon and Weaver's index of diversity, H' (Shannon and Weaver, 1949) as follows:

$$H' = - \sum ((n_i / N) \log_2 (n_i / N))$$

where n_i is the number of individuals of the ith species, N is the total number of individuals of all component species.

To group the moth communities from three sites according to the similarity in species composition or communities structure, we conducted UPGMA cluster analyses based on Pianka's α index (Pianka, 1973) as follows:

$$\alpha = (\sum (n_{1i} n_{2i})) / ((\sum (n_{1i} / N_1)^2 \sum (n_{2i} / N_2)^2)^{1/2} N_1 N_2)$$

where N_1 and N_2 represent the total number of individuals or species in landscape components 1 and 2, n_{1i} and n_{2i} represent the number of individuals or species of ith species or group in Site 1 and 2, respectively.

Feeding habit of larval stage

Feeding habit of larval stage of moth collected was classified into 16 categories such as polypahgy, evergreen and deciduous trees, evergree tree, deciduous tree, grass plant, climbing plant, bamboo, fern, moss, lichen, mushroom, cereal, fruit, falling leaf, comb, and unknown (Kim et al., 1982; Inoue et al., 1982; Sugi et al., 1987).

Results

A total of 3,804 individuals belonging to 727 species from 30 families were captured at the 3 study 1,727 individuals of 505 species (27 families) at Site 1, 1,193 individuals of 353 species (24 families) at Site 2, and 885 individuals of 340 species (25 families) at Site 3. Species richness and individuals of Noctuidae, Pyralidae, Geometridae, and Tortricidae were the highest at all 3 sites. All of species richness, individuals, and species diversity (*H'*) were the highest in Site 1 for 4 years. The index of similarity (α-Index) was higher between Site 2 and 3 in 2006, while higher between Site 1 and 2 in 2009 (Fig. 1).

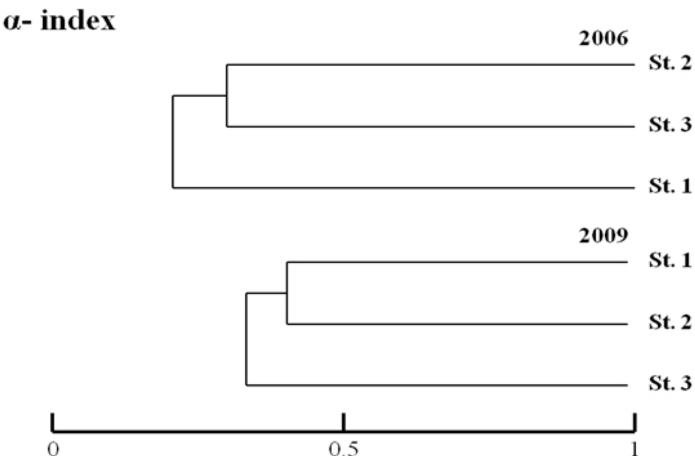

Figure 1. Dendrograms showing the results of UPGMA cluster analysis based on Pianka's overlap index α among moth communities of 3 study sites in Samcheok, Korea in 2006 and 2009.

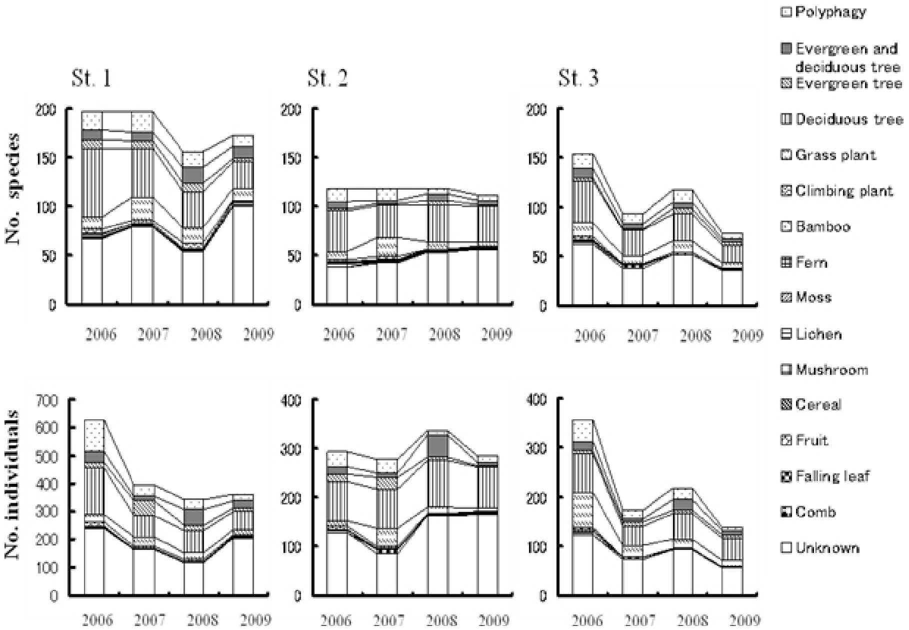

Figure 2. Species richness and individuals of moths of 1 different feeding habit at 3 study sites in Samcheok, Korea from 2006 to 2009.

Moths were grouped into 16 categories by hosts of the larval stage. Individuals of moths of herbaceous feeding habit continuously decreased at Site 3, but proportion of individuals of tree feeding habits continuously increased (Fig. 2).

Discussion

The results revealed that species component, dominant species, and species diversity of moths showed relatively clear difference between unburned area, surface fire area, and crown fire area. However, the present results showed that moth communities was relatively recovered according to vegetation change after forest fire and regeneration of moth communities in surface fire area was more faster than in crown fire area.

It is thought that moths are useful bioindicator to estimate change of forest environment due to having various feeding habit in larval stage. However, for a more detailed understanding of moths as indicator, feeding habit, lifecycle, and movement ability of each species need to be studied more.

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A study on the possibility of *Melia azedarach* L. of planting in sterile land

멀구슬 나무의 척박지 식재 가능성에 관한 연구

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Abstract

This study was analyzed the possibility of planting *Melia azedarach* in sterile land. Seeds propagation made use of seed coat, non-seed coat and air drying. Soil made use of mixed perlite and vermiculite. Without gap of keeping and soil made germination over 75%. Growth was seen maximum height of 1.2m and double storied forests an annual.

요약

본 연구는 척박지에서 멀구슬 나무의 식재 가능성을 분석하였다. 종자 번식은 종피, 종피제거, 양건법을 이용하였으며, 토양은 펄라이트와 버미큘라이트를 혼합하여 사용하였다. 보관방법과 토양의 차이 없이 75%이상 발아가 이루어 졌으며, 생장은 1년에 최대 1.2m의 수고와 복층림을 보였다.

Introduction

Melia azedarach was originated from Asia was introduced from Japan to Korea. Now, it grow in Jeju-do, Gyeongsangnam-do and Jeollanam-do. The tree is used as furniture tree, street tree, landscape tree and fruit is used as medicinal(Tae-Uk Kim, 2002; Seong-Cheon Hong, Su-Hyun Byun, Sam-Sik Kim, 1987).

Study of Coast Salt Affected Environment(Do-Gyun Kim, 2010), it was relatively strong in salty wind and was distributed in inland area as Nepal(Yong-ha Kim, 2009). These conditions presume application to sterile environment.

Methodology

Seed was classified seed coat, non-seed coat and air drying. After storing in ground except air drying, the others carried sowing out in April. A group organized five pot and irrigated 500㎖ without non-nutrient. Each group mixed 1:1 rate and made Soil : Perlite(Group A), Soil : Vermiculite(Group B).

Results and Discussion

It was different among groups and gradually decreased difference In July. After July, so all of group rapidly increased density that it was difficult to measurement.

Table.1. Germination rate by processing method in July

Group / Germi-nation(%)	Group A Soil + Perlite			Group B Soil + Vermiculite		
	Seed coat	Non-seed coat	Air drying	Seed coat	Non-seed coat	Air drying
July	61	93	73	90	60	72

Height measured average, minimum and maximum. Although it was different among groups, it shortly grew in summer. Especially, air drying highly showed average and maximum.

Table.2. Growth by processing method and time

Group / Height (cm)	Group A Soil + Perlite			Group B Soil + Vermiculite		
	Seed coat	Non-seed coat	Air drying	Seed coat	Non-seed coat	Air drying
July	2.5	2.9	2.5	3.1	3.4	3.1
	1.5-4.4	1.5-3.3	1.7-4.6	2.0-5.2	1.8-5.8	1.5-3.4
September	23.8	31.7	47.9	36.6	40.6	45.8
	4.0-64.0	10.0-99.2	3.0-119.0	6.0-108.0	6.0-96.0	7.0-127.0

※ Height(cm) : Average / Min – Max

Germination rate and growth was not closely related. Regardless of keeping of seed, however, it came to rate and fast growth. Study concluded that *Melia azedarach* suited for double storied forests and fast greening.

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Method of manufacturing soil-map of natural regeneration site after forest fire, Goseong.

산불피해 이후 고성지역 자연복원지에 대한 산림토양도 작성

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Abstract

This study was carried out to manufacture soil map of compartment 309, sub-compartment 2, Yang-yang working plan area located in Injeong-ri, Jugwang-myeon, Goseong-gun, Gangwon-do, Korea where natural regeneration site after forest fire. First, soil information and profile survey were conducted in order to obtain information of reconnaissance soil map and soil type for the site. ArcGIS 9.3 program was used for the DEM(Digital Elevation Model) analysis and manufacturing soil map. After DEM was formed with digital map, an altitude, bearing and slope were analyzed. The result showed that the altitude was a little low and comparatively lots of an incline facing north topographies were observed. The slope of 0~20° showed distribution of 44.9ha accounting for 66.4%. Soil map showed that eroded soil was still distributed in 42.6ha, 63% of 67.6ha. The accumulated data after continuous research in the future will be used as preliminary data for the study of natural regeneration site after forest fire.

요약

본 연구는 산불발생이후 자연복원을 실시한 강원도 고성군 간성읍 인정리에 위치한 양양경영계획구 309임반 2소반의 산림토양도를 작성하기 위해 실시하였다. 우선 대상지의 입지구획과 토양형을 결정하기 위해 개황조사와 토양단면조사를 실시하였으며, 자료 분석과 산림토양도는 ArcGIS 9.3프로그램을 사용하여 작성하였다. 수치지형도를 이용하여 DEM을 생성하고 표고, 방위, 경사를 분석하였다. 분석결과 표고는 다소 낮은 것으로 나타났으며, 비교적 북사

면의 지형이 많았다. 또한 경사 분석결과 0~20°의 비율이 66.4%로 44.9ha정도 분포하는 것으로 나타났다. 산림토양도 작성결과 대상지 면적의 63%에 달하는 42.6ha가 여전히 침식토양이 분포하는 것으로 나타났다. 앞으로 조사가 지속적으로 진행되어 자료가 축적되면 자연복원지의 산림토양의 회복과정을 연구하는데 필요한 기초자료로 활용될 것이다.

서론(Introduction)

1996년 고성산불이 발생하기 전까지 산불피해지의 복원정책은 피해지 전 면적에 조림을 하는 것 이었다. 하지만 1996년 고성산불 직후 자연복원의 필요성이 처음 제기 되었고 고성군 죽왕면에 자연복원연구지역이 처음으로 설정되었다. 또한 2000년 동해안 산불 이후 복원방법에 관해 최초로 본격적인 사회적 논의가 이루어지게 되었다(환경부, 2006).

산불피해는 단순히 임목의 피해뿐만이 아니라 산림토양에도 직간접적으로 영향을 주어 유실, 교란, 간섭 등으로 인해 생산성이 감소하게 된다. 임목의 생장에 영향을 미치는 여러 가지 요인이 있다. 이 중에서 지형 및 토양인자를 포함하는 입지환경인자는 입목생장에 결정적으로 영향을 주는 것으로 알려져 있다(김태훈 등, 1988, 1991).

본 연구는 산불발생이후 자연복원을 실시한지 10년이 지난 현재의 산림토양분포를 파악하기 위해 산림토양도를 작성하는데 의의가 있다. 따라서 자연복원지의 산림토양의 회복과정을 규명하는데 필요한 기초자료로 활용될 것이다.

재료 및 방법(Methodology)

1. 연구대상지.

본 연구의 대상지는 산불발생이후 자연복원을 실시한 강원도 고성군 죽왕면 인정리에 위치한 양양경영계획구 309임반 2소반으로 선정하였으며(그림 1), 대상지의 면적은 67.6ha이고, 모암이 조립질 화강함으로 이루어진 지역이다.

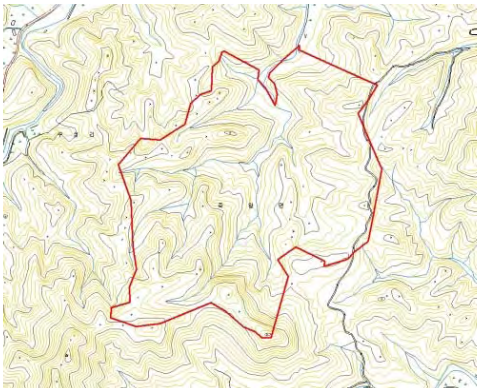

그림 1. 연구대상지

2. 수치지형도

본 연구에서 사용한 수치지형도는 국립지리원에서 제작된 1:5000축적의 수치지도를 사용하였으며, 수치지형도를 이용하여 ArcGIS 9.3 프로그램으로 수치표고모형(Digital Elevation Model)을 생성하였다. 생성된 DEM을 이용하여 대상지 및 표준지의 표고, 방위, 경사 값을 분석하였다.

3. 현지조사자료

연구 대상지의 산림토양도를 작성하기위해 2011년 3~4월에 개황조사 및 산림토양조사를 실시하였다. 개황조사 자료로 산림토양도의 잠정 구획을 실시하였으며, 산림토양조사로 14개의 표준지를 선정하여 입지환경 조사 및 토양단면 조사를 하였으며, 간략조사를 실시하였다. 조사결과는 ArcGIS 9.3 프로그램으로 산림토양도 작성 시 Point자료로 구축하였다.

4. 산림토양도 작성

산림토양도 작성 시 ArcGIS 9.3프로그램을 사용하였다. 항공사진과 개황조사 자료그리고 수치지형도를 이용하여 토양형별 구획을 실시하였으며, 각각의 토양형별 속성은 현지 조사 자료를 이용하여 토양형을 결정하였다.

결과 및 고찰(Results and Discussion)

1. 표고, 방위, 경사 분석결과

대상지에 대한 표고, 방위 경사를 ArcGIS 9.3으로 분석한 결과는 그림 2와 같다. 표고 100m이하인 면적이 45.0ha이며, 100m이상인 면적이 22.6ha로 대상지 전체면적에 대한 비율은 66.6%와 33.4%인 것으로 나타났다(그림 2). 방위는 북, 북동, 북서 사면의 비율이 48.1%로 32.5ha이며 다음으로는 남, 남동, 남서 사면이 30.2%로 20.4ha에 걸쳐 분포하고 있다(그림 3). 경사 분석결과 완경사지와 경사지의 비율이 66.4%로 44.9ha를 차지하고 있다. 반면 절험지는 1.8%로 국소적으로 나타났다(그림 4).

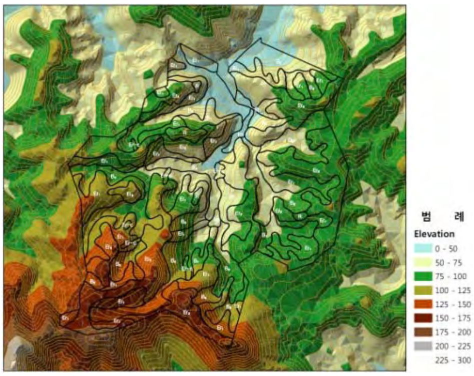

그림 2. 대상지 표고분석 결과

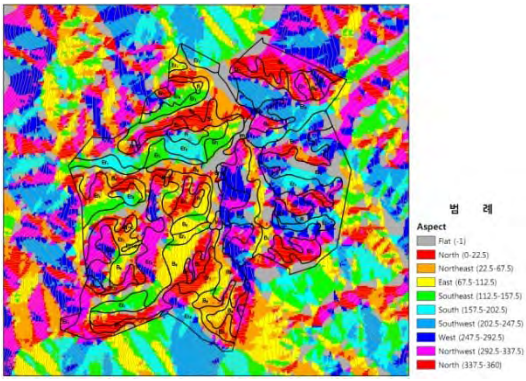

그림 3. 대상지 방위분석 결과

그림 4. 대상지 경사분석 결과

분석결과를 이용하여 조사표준지의 표고, 방위, 경사 값을 획득하였다. 조사표준지의 표고는 42~98m까지 분포하였다. 경사는 0~32.7° 까지 분포한다.

방위는 13.4~357.5° 까지 분포하고, 무방위인 표준지가 1개소로 나타났다.

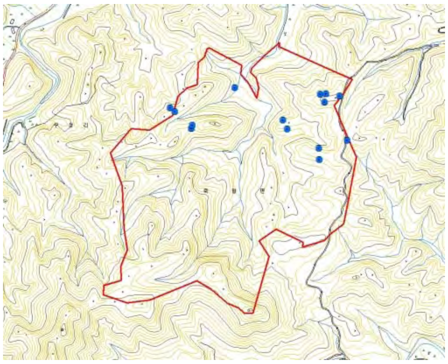

그림 5. 조사 표준지

2. 산림토양도 작성

토양형에 따른 대상지의 산림토양도 작성결과는 그림 3과 같이 나타났으며, 토양형의 분포비율은 다음 표 2와 같다. 침식토양의 면적이 42.6ha로 전체면적 67.6ha중에 63% 분포하고 있으며 갈색산림토양의 비율은 34.3%이다.

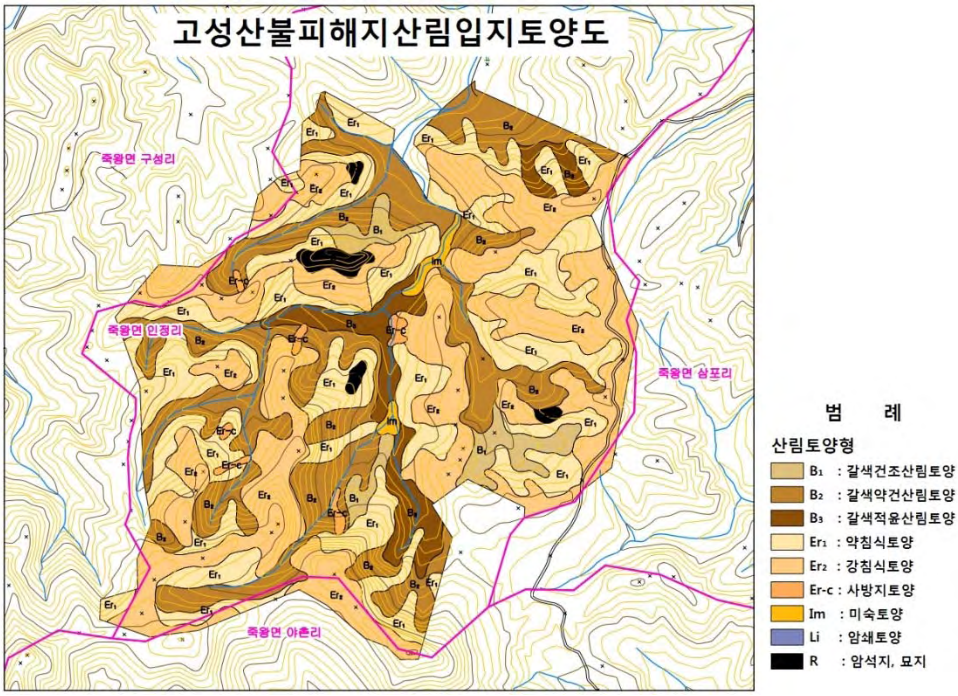

그림 6. 고성산불피해지 산림입지토양도 작성결과

표 2. 토양형별 분포 면적 및 비율

토양형	B_1	B_2	B_3	Er_1	Er_2	Er-c	Im	R
비율(%)	3.7	25.0	5.6	29.3	33.7	0.8	0.7	1.2
면적(ha)	2.5	16.9	3.8	19.8	22.8	0.5	1	0.8

3. 고찰

본 연구에서는 산불이 발생한 후 10년간 자연복원을 실시한 지역의 산림토양도를 작성하였다. 산림토양도 작성결과 여전히 침식토양이 넓게 분포하고 있어 앞으로도 지속적인 조사와 관리방안이 필요하다. 앞으로 복구방법별로 조사 자료가 축적되어, 복구방법에 따른 연도별 토양분포의 변화를 비교한다면 산불피해지의 산림토양 복구 및 관리방법과 회복과정을 연구하는데 중요한 기초자료가 될 것으로 판단된다.

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Effects of edge and burn severity on post-fire vegetation regeneration

산불피해지 식생재생에 대한 가장자리와 피해강도 효과

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Abstract

This study aims to investigate the effects of edges and burn severity on the post-fire vegetation regeneration. Damaged areas of Samchiuck fire in 2000 was selected as the study areas, and we adopt 2 (high and low burn severity) Ｘ 2 (edge areas and interior areas) study design to compare the differences in post-fire vegetation regeneration. To measure burn severity and vegetation regeneration, delta Normalized Burn Ratio(ΔNBR) and delta Normalized Difference Vegetation Index (ΔNDVI) were adopted respectively. GRIDs (1km Ｘ 1km), the unit of analysis, were generated and overlaid covering the entire study areas in GIS. Edge areas were identified as GRIDs touching boundary of damaged areas. The study results indicated that there was a statistically significant difference in vegetation regeneration due to difference in burn severity and edges. The results also suggested that GRIDs with high burn severity and edge areas showed the highest vegetation regeneration while GRIDs with low burn severity and interior areas.

요약

이 연구는 삼척 산불 피해지를 대상으로 피해강도(burn severity)와 가장자리 효과(edge effects)에 따른 식생의 재생력에 대한 영향을 분석하고자 하였다. 피해 강도와 가장자리 효과를 분석하기 위해 2(저강도 피해지역과 고강도 피해지역)x 2(피해지 내부 지역과 가장자리 내역)을 실험 디자인으로 채택하였다. 산불 피해 강도는 인공위성 영상을 기초로 하여 정규탄화지수 변화값

(dNBR)과정규 식생지수 변화값(dNDV)지수를 이용하여 평가하였다. 이 결과에 기초하여 피해 강도와 가장자리 효과가 초기 식생 재생 변화에 주는 영향과 상관관계를 비교 분석하였다. 연구 결과 초기 식생 재생을 나타내는 dNDVI값은 강한 피해강도가 높은 피해지역에서 높으며, 피해지 가장자리 지역일수록 더 높은 것으로 나타났다. 즉 가장자리 지역이 내부 지역보다 재생이 활발하게 이루지는 것으로 나타났다.

서론(Introduction)

산불은 산림생태계와 인간의 삶에 중요한 의미를 갖는다(Gustafson et al., 2004; Nunes et al., 2005). 따라서 산림 과학 분야의 연구자 특히 산림 관리자, 산림 정책 입안자에 의해 중요한 연구 분야로 인식되어 왔다.

산불에 의한 식생에 대한 다양한 변화는 거의 대부분이 피해강도에 의한 것이다. 한편 산불로 생성된 피해지 가장자리 지역은 기온, 풍속, 상대습도와 같은 환경변화요소에 많은 영향을 받는다(Ranney, 1977; Chen et al.,1992). 2000년 발생한 삼척 피해지를 본 연구는 피해강도(burn severity)와 가장자리 효과(edge effects)에 따른 식생 재생 변화를 분석하고, 연소 강도와 가장자리 효과의 복합적 영향이 식생의 재생력에 미치는 영향을 분석하였다.

재료 및 방법(Methodology)

본 연구에서는 한국 동해안에 위치하고 있는 2000년 발생한 삼척피해지를 연구대상지로 선정하였다. 피해지 산불강도를 분석하기 위해서 ERDAS 9.2 program을 사용하여 다중 분광 밴드 영상(Landsat TM)을 기초로 산불피해 이전과 이후의 정규 식생지수 변화값(dNDVI)및 정규탄화지수 변화값(dNBR)을 측정하였다. 피해 후 초기 식생 재생을 분석하기 위해 2000-2002년 영상을 이용하여 정규 식생지수 변화값(dNDVI)을 계산하였다. 가장자리 효과 분석을 위해 ArcviewGIS 3.3를 사용하였으며, 1x1km 격자를 피해지 전체를 포함하도록 생성하였다. 피해 강도와 가장자리 효과를 분석하기 위해 2(저강도 피해지역과 고강도 피해지역)x 2(피해지 내부 지역과 가장자리 내역)을 실험 디자인으로 채택하였다. 피해 강도에 따른 초기 식생 변화와 피해강도와 가장자리 효과의 복합적 영향에 따른 초기 식생 재생 변화를 각각T-test와 Pearson의 상관 분석을 통해 분석하였다.

결과 및 고찰(Results and Discussion)

산불강도(저강도 피해지역과 고강도 피해지역)별 식생재생 차이(Table 1)를 비교한 결과식생 재생 변화량은 피해 강도가 높은 지역에서 0.555로 나타났다. 즉 피해강도가 낮은 지역 (-0.037)의 비해 식생 재생 변화량이 상당히 높은 경향을 보였다. 따라서 고강도 지역에서 식생재생이 빠르게 일어난 것으로 나타났다. 두 표본 간의 평균 차이에 대한 통계량은 14.464로 유의수준 5%에서 통계적으로 유의한 차이가 있는 것으로 나타났다. 이는 높은 피해 강도에서 식생의 소멸로 인공위성에 낮아진 식생 반사율이 감지된 것이 원인이며, 같은 원리로 인해 낮은 피해 강도에서는 상반된 결과를 보였다.가장자리 효과는 T-test분석으로 가장자리지역과 내부 지역의 dNDVI가치가 통계적으로 서로 차이가 나는 것으로 평가되었다. Table 2에 따르면, T-test한 결과 가장자리 지역의 초기 식생 재생 변화량은 0.01으로 산림 내부 지역의 초기 식생 재생 변화량보다 0.004높은 것으로 나타났다. 그러나 이는 유의 수준 5%에서 유의확률 0.18을 보여 통계적으로 유의수준은 비교적 낮은 것으로 나타났다

Table 3. T-test on dNDVIaccording to burn severity

Variable	Burn severity	Mean	t-value	P
dNDVI	High burn severity	0.055	14.464	0.000
	Low burn severity	-0.037		

Total number of plots=23l, Number of plots in high burn severity= 117, Number of plots in low burn severity= 114

Table 4. T-test on dNDVIaccording to forest region

Variable	Forest region	Mean	t-value	P
dNDVI	Forest edge	0.010	-1.337	0.182
	Forest interior	0.006		

Total number of plots=23l, Number of plots in forest edge= 165, Number of plots in forest interior= 66

Table 3은 피해 강도와 가장자리 효과의 복합적 영향을 분석하기 위해 2x2 교차 분석에 대한 일원배치 분산 분석 결과이다. 결과에 따르면 고강도 가장자리 지역에 속하는 그룹 D가 0.059로 재생 변화량이 가장 높은 것으로 나타났다. 다음으로 고강도 내부지역인 그룹C(0.049), 그룹B(-0.036), 그룹A(-0.039) 순으로 나타났다. 즉 초기 식생 재생변화량을 나타내는 dNDVI값은 피해강도가 높은 피해 지역에서 높게 나타났으며, 피해지 가장자리 지역일수록 더 활성화 되는 것으로 나타났다.

따라서 식생의 재생 변화에피해 강도의 영향이 크게 작용하며, 이에 가장자리 효과가 복합적으로 작용하여 초기 식생 재생 변화량에 영향을 주는 것

으로 나타났다.

Table 5. One-way ANOVA for four groups

	N	Mean	Std. Dev	Min	Max
A	31	-0.039	0.041	-0.099	0.112
B	83	-0.036	0.056	-0.209	0.140
C	35	0.047	0.052	-0.036	0.188
D	82	0.059	0.040	-0.083	0.151
Total	231	0.009	0.067		

A:저강도-내부지역, B:저강도-가장자리지역, C:고강도-내부지역, D:고강도-가장자리지역

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Assessing Canopy Fuel Characteristics for Major Conifer Species in Korea

우리나라 주요 침엽수종에 대한 수관층 연료특성 평가

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Abstract

The objective of this study was to assess and analyze the hazard of crown fires based on the canopy fuel characteristics of major conifer stands in Korea. This study was also developed allometric equations for the canopy fuel load and canopy base height of the major conifer stands using the allomeric equations of biomass developed by the Korea Forest Research Institute (KFRI) and the data from the 5th National Forest Inventory (NFI). The adjusted multiple coefficient of determination of the developed models ranged from 0.63 to 0.99 for canopy fuel load and 0.61 to 0.85 for canopy base height. The suggested models in this study could provide reasonable characterization of the canopy fuel load which is very significant in forest fire management in Korea

요약

본 연구의 목적은 우리나라 주요 침엽수종에 대한 수관층 연료특성을 평가하고자 하였다. 본 연구에서는 국립산림과학원(KFRI)에서 제시한 바이오매스 상대생장식과 제 5차 국가산림자원조사(NFI) 자료를 이용하여 우리나라에 분포하는 주요 침엽수종에 대한 수관연료량과 지하고 추정모델을 개발하였다. 본 연구에서 제시된 수관연료량 추정식의 조정결정계수는 0.63～0.99, 지하고 추정식의 조경결정계수는 0.61～0.8로 나타났다. 본 연구에서 제시된 우리나라 주요 침엽수종에 대한 수관층 연료특성의 분석 결과는 산불 관리에 유용한 정보를 제시해 줄 것으로 사료된다.

Introduction

Conifer stands have the widest distribution of forests in Korea. These stands are very dense because thinning operations are not completely being done in these forests. Therefore, fire hazard is very high and abundant in these stands(Koo *et al*., 2010).

Canopy fuels are the main fuel layer supporting canopy fire spread. Canopy structure largely determines combustion requirements and outputs, and consequently important fire behavior descriptors such as rate of fire spread and fire intensity(Gragam *et al*., 1999). Therefore, study on canopy fuel characteristics is urgently needed to suppress the crown fires that are frequently occurring in conifer stands. Thus, the objectives of this study were to analyze canopy fuel characteristics (canopy fuel load, canopy base height, canopy bulk density) and develop allometric equations for the canopy fuel load estimation of major conifer stands in Korea.

Methodology

The present study was conducted to determine the forest fuel types that are subject to the incidence of crown fires. The definition of the fuel complexes in this category was based on historic fire regime characteristics and published fire case studies(Rothermel, 1991). The variety of fuel complexes was further reduced given the available data in the National Forest Inventory (NFI) dataset covering certain forest types. The six major fuel types were categorized on the basis of the NFI forest cover type data and these were Central region *Pinus densiflora*, Gangwon region *Pinus densiflora, Pinus thunbergii, Pinus rigida, Larix leptolepis* and *Pinus koraiensis*.

The stand and individual tree data source selected for this study was the National Forest Inventory (NFI). Canopy fuel load were analyzed using the database of the allomeric equations for biomass developed by the Korea Forest Research Institute (KFRI).

Within the present study it was reasoned that, given the previous statistical analysis, linear regression analysis was used to develop models for predicting canopy fuel load (CFL) and canopy base height (CBH) from commonly measured forest stand descriptors(Cruz *et al*., 2003). Given the heteroscedasticity present in the relationship between CFL, CBH and basal area, stand density, stand height and the consequent violation of required assumptions of linear regression analysis, these two variables were modeled using logarithmic transformation.

Results and Discussion

Among the six broad fuel types, *Pinus koraiensis* had the highest mean CFL, 2.09kg/m², followed by Gangwon region *Pinus densiflora* 1.51kg/m², *Pinus thunbergii* 1.31kg/m², *Pinus rigida* 0.74kg/m², Central region *Pinus densiflora* 0.63kg/m² and *Larix leptolepis* 0.53kg/m². Among the species, *Pinus thunbergii* had the highest CBH. Furthermore, the CBH of six species did not show much variability between fuel types but in the CFL and CBD higher variations were observed.

The CBD of *Pinus koraiensis* was the highest among the different trees while on the other hand, the CBD of Central region *Pinus densiflora* was the lowest among the different trees observed. Given the individual tree and stand structural differences among the fuel types considered in this study, the models to be developed were fuel type specific. From the linear relationships and non-homogeneity of variance found in CFL and the explanatory variables under analysis, linear regression analysis of log transformed data was used to model CFL as a function of stand density and basal area. The adjusted multiple coefficient of determination of the developed models ranged from 0.63 to 0.99 for CFL. The adjusted multiple coefficient of determination of the developed models ranged from 0.61 to 0.85 for CBH.

The study was conducted with an objective of assessing and analyzing the hazard of crown fire based on the canopy fuel characteristics of major conifer stands in Korea. Although not formally evaluated, the models seem to give a reasonable characterization of the canopy fuel which is very significant in forest fire management applications(Cruz *et al.*, 2003).

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Crown Characteristics and Fuel Load Estimation of *Pinus densiflora* S. et Z. in Gyeongbuk Province

경북지역 소나무림의 수관 특성과 연료량 추정

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Abstract

The objective of this study was to develop allometric equations for predicting crown fuel load based on the crown characteristics of *Pinus densiflora* trees in Gyeongbuk province. The proportion of available crown fuel load in total crown fuel load was observed to be 48.7%. Diameter at breast height variable in the model explained 89%, 93%, 95% and 96% of the observed variation ($P < 0.05$) in the needles, available crown fuel load, total branch and total crown fuel load, respectively from regression models that were developed for estimating fuel load. On the other hand, crown length and crown width together explained 79%, 77%, 68% and 72% of the observed variation ($P < 0.05$) in the needles, available crown fuel load, total branch and total crown fuel load, respectively. The results showed that the crown length and crown width combine together as independent variables performed better and had higher R^2 on all fuel loads but had lower R^2 when used separately. The suggested allometric equation in this study could provide quantitative fuel load attributes for crown fire behavior modeling of *Pinus densiflora* stands in Gyeongbuk province.

요약

본 연구의 목적은 경북 지역에 분포하는 소나무림을 대상으로 수관 특성에 따른 연료량을 추정하기 위한 상대생장식을 개발하고자 하였다. 경북지역 소나무림의 수관연료량 비율은 잎 22.9%, 직경 1cm이하 가지 25.8%로 이

용 가능한 수관연료량은 약 48.7%인 것으로 나타났다. 연료량 추정을 위한 회귀 모델은 흉고직경을 독립변수로 한 식이 모든 연료량추정식에서 결정계수 90%이상으로 매우 높게 나타났으며, 수관 길이와 수관 폭은 함께 사용했을 경우 결정계수가 68%~79%로 각각 독립변수로 사용할 경우 보다 비교적 결정계수가 높아지는 것으로 나타났다. 본 연구는 경북지역 소나무림의 다양한 수관 특성을 이용한 상대생장식 개발을 통해 수관화 모델에 대한 정량적인 정보를 제공해 줄 수 있다.

Introduction

Forest fire brings many damages on ecological, economical and social aspects such as change in climate caused by increase of carbon dioxide emission, loss of lumber, forest products income, disturbance on industry and worst injuries and even casualties among human(Korea Forest Service, 2011). In order to minimize and control forest fires, interest and efforts in predicting fire behavior in many countries are significantly increasing. Estimating the crown fuel load is very important in order to predict fire behavior such as crown fire intensity, flame length, fuel consumption during crown fire and crown fire severity(Mitsopoulos and Dimitrakopoulos, 2007). Thus, this study was conducted to develop allometric equations for the crown fuel load estimation based on various crown characteristics of *Pinus densiflora* in Korea.

Methodology

1. Data collection

This study investigated *Pinus densiflora* stands in Youngju, Bonghwa and Daegu region in Gyeongbuk Province. Field measurements were done such as height of tree, diameter at breast height, crown width and crown length before the sample trees were cut 0.2m above the ground(Kucuk et al., 2007). After the trees were cut, the stem of each tree was cut on a 1m interval. Crown fuel load estimate were classified into stem, needles, and branches(<0.5cm, 0.5~1cm, 1~2cm, 2~4cm, >4cm) and the weight of each crown fuel load were measured. Sampled fresh weights of each crown fuel load were also measured and then brought to the laboratory for drying. Samples were dried at 95°C for 240hrs and their dry weights were measured.

2. Statistical analysis

Correlation and regression analyses were frequently performed in order to determine the relationship between two variable, Using these two analysis together will give very significant results(Bilgili and Kucuk, 2009). Thus this study utilized both correlation and regression analysis. Correlation between different crown characteristics such as diameter at breast height, crown base height, height of the tree, crown length and crown width and needles fuel load, available crown fuel load(needles and <1cm branches), total branches fuel load, and total crown fuel load were analyzed. On the other hand, results of the correlation analysis on the crown characteristics was used as the independent variables while crown fuel loads was used as dependent variables in the regression analysis that were conducted. Lastly, logarithm regression model was used for predicting needles, branches and total biomass.

Results and Discussion

1. Crown characteristics and distribution

The observed mean diameter at breast of the sample trees in Gyeongbuk province was 16.83cm while the mean crown base height was 4.32m. On the other hand, the average height of the trees was 9.48m. The crown length of the sample trees ranged from 2.78m to 9.20m while the for the crown width, it ranged from 0.39m to 3.11m. The average needle fuel load and available crown fuel load (needles and <1cm branches) were 5.13kg and 11.13kg, respectively while total branches fuel load and total crown fuel load were 18.10kg and 23.23kg, respectively. The relative proportion of needles and branches(<0.5cm, 0.5~1cm, 1~2cm, 2~4cm, >4cm) in total crown fuel load were 22.9%, 13.25%, 12.59%, 15.55%, 26.19%, 10.34%, respectively. The proportion of available crown fuel load was 48.74%.

2. Crown fuel load

Correlation analysis results showed that the diameter at breast height was closely related to all fuel loads. On the other hand, crown length and crown width were correlated well with the needles fuel load, available crown fuel load, total branches fuel load and total crown fuel load. Regression equations to predict crown fuels were based on the relationship between crown characteristics such as diameter at breast height, crown length and crown width to the crown fuel. The developed allometric equation for the crown fuel load estimation based on the diameter at breast height, crown length and crown width were highly significant. The diameter at breast height variable alone explained 89%, 93%, 95% and 96% of the observed variation ($P < 0.05$) in the needles, available crown fuel load, total branch, and total crown fuel load, respectively. Crown length and crown width together explained 79%, 77%, 68% and 72% of the observed variation ($P < 0.05$) in the needles, available crown fuel load, total branch, and total crown fuel load, respectively.

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Estimations of Biomass and Carbon Stocks in the different Forests Types of the Philippines

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Abstract

The most abundant Greenhouse gas in the earth's atmosphere is the carbon dioxide. The concentration of CO_2 has gradually increased by more than 30% since the pre-industrial times. Combustion of fossil fuels and deforestation are the main reasons why CO_2 is still increasing at unprecedented rate with an average of 0.4% per year. Thus, forest ecosystem can be considered as one of the major sources of C. In the Philippines, the C densities in natural forest diminished by approximately 50% after converting it into tree plantations or agricultural lands, whereas deforested and degraded lands with grasses has a C density of <15 Mg ha^{-1}. On the other hand, this ecosystem is also considered as the major sinks for the C. The estimated C pool in the Philippine forests is approximately 1,100 Tg C.

Introduction

Scientists are saying that the earth is continuously warming. This phenomenon is called global warming. It is defined by Raga-as (2004) as a phenomenon of increasing global surface temperature and the potential climate change of global magnitude in response to the accumulation of atmospheric "greenhouse gases" predominantly CO_2 that is believed to have the greatest influence on global climate. According to Contreras (1997, as cited by Raga-as, 2004), the Intergovernmental Panel for Climate Change (IPCC) confirmed in 1990 during its First Scientific Assessment of Climate Change that there is a global warming. In the second assessment of IPCC in December 1995, greenhouse gases in the atmosphere were confirmed increasing (Raga-as, 2004). Strong evidence was concluded in the Third Assessment Report that human activities have affected the world's climate reported by the IPCC in 2001 (Lasco et al., 2004a).

The United Nations Framework Convention on Climate Change (UNFCCC) defined climate change as a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods (Lasco et al., 2004a). Greenhouse gases allow short-wave radiation to pass through the earth but prevent the release of long-wave radiation at the earth surface from escaping to outer space (Lofrangco, 2006). Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (NO_2), chlorofluorocarbons (CFCs) and ozone (O_3) are considered Greenhouse gases (GHGs). Among GHGs, CO_2 is considered as the most abundant in the earth's atmosphere. According to Lasco et al. (2004a), the concentration of CO_2 has gradually increased by more than 30% since the pre-industrial times. He also noted that combustion of fossil fuels and deforestation are the main reasons why CO_2 is still increasing at unprecedented rate of an average of 0.4% per year. Its concentration has gradually increased over the years from 280 ppm during the pre-industrial period (1750-1800) to 353 ppm in 1990 (IPCC, 1990 as cited by Lofrangco, 2006). From 1980 to 1990, C was the biggest green gas emitted into the atmosphere with 55% followed by CFC (17%), methane (15%), nitrous oxide (6%) and others (7%) (Raga-as, 2004). Approximately, 20.2 B tons of CO_2 were emitted in the atmosphere in 1994. In the Philippines, the forestry sector released C by means of deforestation, forest fires, and loss of C sinks by about 67% followed by the energy sector with 30% and industry with 3% (Raga-as, 2004). Murdiyarso (1996 as cited by Raga-as, 2004) stated that the C emission in the Philippines is 128.6 M tons annually.

Biomass and Carbon density in the different forest land covers in the Philippines

Biomass represents the amount of C in the forest vegetation and it is measured to estimate the amount of C held by the forest (Raga-as, 2004). The trunk, branches and leaves of a tree is considered as aboveground biomass while roots are known as belowground biomass. Other C pools or a system which has the capacity to accumulate or release C in forest ecosystem are understory/ herbaceous, litters, necromass and soil. Using the aboveground biomass of the tree, the C stored for each tree can also be computed. According to Pulhin (2008), the typical biomass dry weight of a plant is ranging from 45% to 55% C and the recommended for the tropical trees is 47% (IPCC, 2006).

The estimated C density in the Leyte Geothermal Reservation were 392.96 Mg ha^{-1}, 186.31 Mg ha^{-1}, 192.09 Mg ha^{-1}, 275.42 Mg ha^{-1}, 294.16 Mg ha^{-1}, 196.75 Mg ha^{-1}, and 114.72 Mg ha^{-1} for the forest areas, shrubs/brush lands, Mahogany plantation, Mangium plantation, Gmelina plantation, Coconut, and Abaca/banana, respectively (Lasco et al. 2002). Raga-as (2004) conducted a study entitled "Comparison of Carbon Benefits between Natural and Plantation Forest in Aurora Province, Philippines". The total biomass densities were 131.3 Mg ha^{-1} and 72.2

Mg ha^{-1} for the natural and plantation forest, respectively. The computed C stock densities were 194.4 Mg ha^{-1} and 125.8 Mg ha^{-1} for the natural and plantation forest, respectively.

Lasco et al. (2004b) found out on their study that the average tree biomass density in the secondary forest of Mount Makiling Forest Reserve was 576 Mg ha^{-1}. On the other hand, the C stock density of this forest reserve was approximately 418 Mg ha^{-1} including the soil organic C. The multi-story agroforestry system in Mt. Makiling also has a biomass density accumulation of 236 Mg ha^{-1}. The C stock density was estimated to 105.2 Mg ha^{-1} (Sales, 1998, as cited by Palijon, 2009). In contrast, grassland areas such as dominated by *Imperata cylindrica* and *Saccharum spontaneum* had an 8.9 and 15.2 Mg ha^{-1} C density respectively which is much lower than forested areas.

In the case of the La Mesa Watershed, the average tree biomass density for the 11 tree plantation species was 66.62 Mg ha^{-1} (Lasco and Pulhin, 2006). On the other hand, the C density of these tree plantations ranged from 40 Mg ha^{-1} to 106 Mg ha^{-1} with an average of 66 Mg ha^{-1}. The pure mahogany plantation had the lowest C density with 40 Mg ha^{-1}, whereas the kaatoan bangkal plantation exhibited the highest with 106 Mg ha^{-1}.

In the mixed *P. kesiya* forest of La Trinidad, Benguet, the estimated averagebiomass of this forest was 125.77 Mg ha^{-1}. Using the IPCC default value of 47%, a total of 59.11 Mg ha^{-1} were the carbon stocks present in the biomass of trees in this forest. The average biomass density of *P. kesiya* trees was estimated 103.79 Mg ha^{-1} whereas for the other non species *P. kesiya* it was 29.31 Mg ha^{-1} (Lumbres et al., 2011)

In terms of mean annual increment (MAI) or the amount of C sequestered by a forest cover in a year, the secondary forest can sequester 0.9 Mg ha^{-1} yr^{-1} and 1.1 Mg ha^{-1} yr^{-1} in Leyte and in Mindanao, respectively. The average C MAI for this type of forest cover is 1.1 Mg ha^{-1} yr^{-1}. In the case of tree plantation, the Benguet pine (*Pinus keyisa)* plantation can increase their biomass about 8.3 Mg ha^{-1} yr^{-1} while their C MAI is approximately 3.7 Mg ha^{-1} yr^{-1} using a 45% C content percentage. On the other hand, Benguet pine plantation with broadleaf species in Nueva Ecija has a biomass MAI of 6.4 Mg ha^{-1} yr^{-1} while its C MAI is 2.9 Mg ha^{-1} yr^{-1} (Sakurai et al. 1994, as cited by Lasco et al., 2004a). The Agoho *(Casuarina equisitifolia*) plantation in Iloilo has a biomass MAI of 3.9 Mg ha^{-1} yr^{-1} while the C MAI was about 1.7 Mg ha^{-1} yr^{-1} (Lachica et al. 1994, as cited by Lasco et al., 2004a). The averages for the forest plantations land cover that were cited in the primer were 9.1 Mg ha^{-1} yr^{-1} and 4.2 Mg ha^{-1} yr^{-1} for the biomass and C MAI, respectively (Lasco et al., 2004a). The forest plantations can sequester more C annually than the secondary forest. This result is expected because most of the species planted in the forest plantation in the Philippines are fast growing as compared to secondary forest. But old growth forest exhibit the most C stored in their biomass followed by the secondary forest, tree plantation, agroforestry and grassland, respectively (Lasco et al., 2004a).

In the urban forest, Lofrangco (2006) conducted a C stock assessment in a golf course in Mandaluyong City. The estimated aboveground biomass was 233.12 Mg ha^{-1} while the C stock density was approximately 104.9 Mg ha^{-1}. On the other hand, Florindo (2007) studied the west course of this golf course and found that the aboveground biomass was 1,379.50 Mg and C stored was 620.78 Mg. In terms of C density, the estimated total aboveground biomass and C stocks were 93.22 Mg ha^{-1} and 41.95 Mg ha^{-1}, respectively. Furthermore, Lumbres (2009) studied the biomass and C stocks available in the Burnham Park in Baguio city. In this study, the estimated aboveground biomass or tree biomass was approximately 4,970.86 Mg with 2,236.89 Mg of C while the belowground biomass or root biomass was approximately 634.11 Mg with 285.35 Mg of C that was stored in the Burnham Park. The total biomass density was 162.66 Mg ha^{-1}, whereas the carbon density was 73.20 Mg ha^{-1}.

In an overall estimation, Lasco and Pulhin (2009) reported that the Philippine forest lands have approximately 1,100 Tg C. They also concluded that a reduction of approximately 50% of C density was observed after the conversion of a natural forest into tree plantation and perennial crop. Furthermore, 10 Mg ha^{-1} yr^{-1} and 3 Mg ha^{-1} yr^{-1} of C were sequestered by fast growing species and slow growing species, respectively through reforestation activities in the degraded forest lands (Lasco and Pulhin, 2009).

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Hot Spot Analysis on Forest Carbon Stock using Getis-Ord Gi* Spatial Statistic

Getis-Ord Gi* 공간통계량을 이용한 산림탄소저장량 핫스팟 분석

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Abstract

In order to acquire higher reliability, spatially explicit quantification of carbon stock is needed. Also an exploration of spatial cluster for high forest carbon is needed for effective forest management plan. In this study, therefore, we produced forest carbon map and explored carbon hot spot. For this, forest stand variables were extracted from NFI data and used to develop aboveground biomass(AGB) regression models by species. Dominant/semi-dominant height and crown density were used as explanatory variables of AGB regression models. Spatial distribution of AGB could be estimated using AGB models, forest type map and the height map that was developed using forest type map and height regression models. Finally, mean carbon per hectare in Danyang county by this spatial modeling was 52.24 tonC/ha and same statistic by existing forest statistical method was 52.79 tocC/ha. These means were not significantly different at p=0.05 using paired t-test. Then we explored hot spot that was clustered with high forest carbon stock using Getis-Ord Gi* spatial statistic. Hot spot above 2.58 standard deviation was distributed in east of Danyang county and cold spot below -2.58 standard deviation in west of Danyang county. Most of hot spot consists of natural forests(88.42%). Major forest type of hot spot was broad leaved forest(57.79%). Major age, DBH and density class of hot spot were IV & V class(69.47%), above medium DBH class(98.74%) and high density class(73.55%), respectively.

요약

온실가스통계의 높은 신뢰도를 확보하기 위해서는 IPCC 우수실행지침 수준 3에 기반한 공간적으로 명확한 산림탄소저장량의 정량화가 필요하다. 또

한 효율적인 산림경영계획 수립을 위해 산림탄소저장량이 높은 지역과 낮은 지역이 밀집하고 있는 공간 클러스터를 파악할 필요가 있다. 따라서 본 연구에서는 충북 단양군의 지상부 바이오매스를 대상으로 산림탄소지도를 제작하고 산림탄소저장량 핫스팟을 탐색하였다. 공간적으로 명확한 산림탄소저장량 분포를 추정하기 위해 국가산림자원조사 표본점 단위로 계산된 산림탄소저장량을 임상도를 이용하여 공간규모를 확장(upscaling)하였다. 그 결과 단양군 산림탄소저장량은 3,329,451 tonC, 헥타 당 평균은 52.24 tonC/ha로 추정되었다. 기존의 NFI 자료 중심의 비례배분법으로 산출된 평균 52.79 tocC/ha과 T-검정 결과 t=0.177 (p>0.05)로 두 가지 방법간 평균 차이는 통계적으로 유의하지 않다. 산림탄소지도를 대상으로 Getis-Ord Gi* 공간통계량을 이용하여 높은 탄소저장량이 밀집한 지역인 산림탄소저장량 핫스팟 지역을 탐색하였다. 분석 결과 표준편차 2.58 이상의 높은 탄소저장량이 공간적으로 집중된 핫스팟은 단양군 동쪽에 분포하고 있으며 표준편차 -2.58 이하의 낮은 탄소저장량이 공간적으로 밀집한 콜드스팟은 단양군 서쪽에 분포하고 있었다. 핫스팟의 대부분은 천연림(88.42%)으로 구성되었으며 활엽수가 가장 많은 면적(57.79%)을 차지하고 있었다. 임분 특성의 경우 4, 5영급(69.47%), 중경목과 대경목(98.74%)이 점유하고 있으며 소밀도가 밀한 지역으로(73.55%)으로 분석되었다.

Introduction

In order to acquire higher reliability, spatially explicit quantification of carbon stock based on IPCC GPG tier 3 is needed. But existing forest statistics has limit for interpretation of spatial distribution of forest carbon because it is aggregated by administrative unit. Also an exploration of spatial cluster for high forest carbon is needed for effective forest management plan. In this study, to solve these problems we produced forest carbon map and explored carbon hot spot using Getis-Ord Gi* statistic.

Methodology

In order to upscale forest carbon from plot into landscape level, forest stand variables compatible with attributes of forest type map were extracted from NFI data and used to develop AGB regression models by species. Dominant/semi-dominant height and crown density were used as explanatory variables of AGB regression models.

Spatial distribution of AGB was estimated by AGB regression models by species which were combined with stand height map that was developed using forest type map and height regression models, and layers of forest type map such as species, crwon density. Then AGB was converted to carbon stocks using CF(carbon fraction of dry matter) 0.5.

Paired T-test for 117 plots was used to test mean difference of carbon between existing method based on National forest inventory data alone and spatial modeling method suggested by this study. Finally, we explored hot spot that was clustered with high forest carbon stocks using Getis-Ord Gi^* spatial statistic. The standardized $Gi^*(d)$ is defined as

$$G_i^*(d) = \frac{\sum_j w_{ij}(d)x_j - W_i^*\bar{x}}{s\{[(nS_{1i}^*) - W_i^{*2}]/(n-1)\}^{1/2}}, \quad \text{all } j.$$

Where *wij(d)* is a symmetric one/zero spatial weight matrix with ones for all links defined as being within distance d of a given *i;* $W_i^* = Wi + wii$, $S^*_{1i} = \sum_j w_{ij}^2$ (all *j*). $\bar{x}$ and s^2 denote the usual sample mean and variance.

Results and Discussion

Mean carbon per hectare in Danyang county by this spatial modeling was 52.24 tonC/ha and same statistic by existing forest statistical method was 52.79 tocC/ha. These means were not significantly different at p=0.05 using paired t-test. Then we explored hot spot that was clustered with high forest carbon stock using Getis-Ord Gi^* spatial statistic. Hot spot above 2.58 standard deviation was distributed in east of Danyang county and cold spot below -2.58 standard deviation in west of Danyang county. Most of hot spot consists of natural forests(88.42%). Major forest type of hot spot was broad leaved forests(57.79%). Major age, DBH and density class of hot spot were 4 & 5 class(69.47%), above medium DBH class(98.74%) and high density class(73.55%).

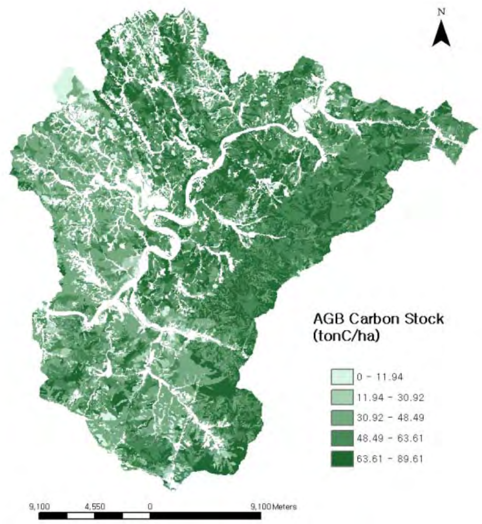

Figure 7. Forest carbon map (2009)

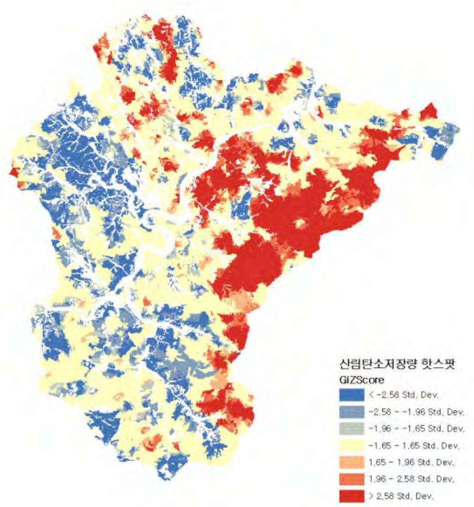

Figure 8. Hot Spot of Forest carbon (2009)

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Physiological Responses of *Pinus densiflora* by seawater watering

바닷물 살포에 의한 소나무의 생리반응 변화

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Abstract

The object of this study is to provide a method to minimize harmful influence on *Pinus densiflora* putting out forest fire using seawater, and then physiological response of Pinus *densiflora* is investigated after watering seawater.

Five-year-old *Pinus densiflora* seedlings treated with seawater according the leafing stages (1 stage: bud, 2 stage: buds swell and new shoot growing, 3 stage: new needle sprouting). Seedlings were measured for shoot growth, photosynthetic responses and analyzed for chlorophyll contents. The shoot growth of all of the treated individuals shows almost no differences compared with those of controls, but some individuals in treatment of leafing stage 3 were withered and appeared browning in top of shoot. The photosynthetic rate in treatments of leafing stage 1 and 2 decreased after 14 days of treatment and has recovered after 28 days of treatment. The rate in treatment of leafing stage 3 drastically decreased and has not recovered completely. The net apparent quantum yield and carboxylation efficiency decreased in treatment of leafing stage 3 only. The chlorophyll contents did not change very much comparing with those of control.

요약

바닷물을 이용한 산불진화 시에 소나무에 미치는 악영향을 최소화할 수 있는 방법을 마련하기 위하여, 바닷물 살포에 의한 소나무의 생리적 반응을 조사하였다. 바닷물 살포는 개엽 단계별(1 단계: 눈(芽), 2단계: 눈이 부풀고 신초가 자라는 단계, 3단계: 신초에서 잎이 트는 단계)로 처리하고 신초생장, 광합성율 변화, 광화학계와 탄소고정계 반응 특성, 엽록소함량을 측정하였다. 신초생장은 모든 처리구에서 양호하였으나 개엽 3단계부터 신초 상단에 가시적인 피해가 나타났다. 광합성율 변화는 개엽 1, 2단계 처리에서 일시적으로 감

소하나 처리 28일 후 회복하였고 개엽 3단계 처리는 완전히 회복하지 못하였다. 순양자수율과 탄소고정효율은 개엽 3단계 처리부터 감소하였다. 엽록소 함량은 대조구 대비 유의적 차이는 나타나지 않았다. 따라서 개엽 3단계 이후 바닷물을 이용한 산불진화를 할 경우, 소나무 잎의 생리적인 감소를 초래할 수 있을 것으로 사료된다.

서론(Introduction)

최근 극심한 가뭄으로 인한 물 부족의 심각성이 대두되면서 산불발생시 담수에 의한 진화에 어려움이 있으며, 있으며 특히 대형 산불이나 동절기 산불의 경우 담수만으로 진화하는데 한계가 있어 바닷물을 이용하여 산불을 진화하고자 하는 시도가 있다. 국제적으로는 이탈리아 등 지중해 연안 국가나 유럽의 프랑스에서도 산불진화 시에 바닷물을 사용하고 있으며 근년 들어 일본에서도 도서지방이나 해안가에서 산불이 발생한 경우 바닷물을 살포하여 산불을 진화하고 있다. 그러나 국내에서는 산불진화에 바닷물을 사용한 사례가 없고 바닷물 살포가 산림생태계에 미치는 영향에 대한 연구 자료가 미흡하여 현실적으로 적용하기 어려운 실정이다. 따라서, 이 연구는 동해안 산불위험지역 산림의 주 수종인 소나무를 대상으로 바닷물 살포에 대한 영향을 개엽 단계별로 파악하여 바닷물을 이용한 산불진화 시에 산림생태계 구성인자인 소나무에 미치는 악영향을 최소화할 수 있는 방법을 마련하는데 그 목적이 있다.

재료 및 방법(Methodology)

실험목은 소나무(*Pinus densiflora*) 5년생 묘목을 사용하였으며 바닷물 살포 처리는 개엽 단계별(1단계: 눈 단계, 2 단계: 눈이 부풀고 신초로 자라는 단계, 3단계: 신초가 다 자라 잎눈이 트는 단계)로, 1단계는 4월18일, 2단계는 4월27일, 3단계는 5월 2일에 물뿌리개를 사용하여 8L/㎡의 바닷물을 살포하였다. 바닷물 살포 후, 눈과 신초의 길이 생장을 모니터링 하였으며 LED light source와 CO_2 injector system이 부착된 휴대용 광합성 측정기(Li-6400, Li Cor.)를 사용하여 광도 PPFD 1000 umol m^{-2} s^{-1} 에서의 광합성율 변화를 모니터링 하였다(Figure 1). 또한 광 변화에 따른 광합성 변화(light response curve)을 측정하여(Figure 2) 암호흡, 최대광합성능력, 순양자수율(net apparent quantum yield)을 구하고 CO_2농도 변화에 따른 광합성 변화(A-*Ci* curve)을 측정하여 광호흡과 탄소고정효율(carboxylation efficiency)을 구하였다. 엽록소 함량은 DMSO법과

Arnon(1949)의 방법을 이용하여 엽록소 a, b, 엽록소 a+b 및 엽록소 a/b을 산출하였다.

결과 및 고찰(Results and Discussion)

바닷물 살포처리에 따른 신초의 길이생장을 모니터링한 결과, 처리구의 일평균 상대생장율은 모두 대조구와 비교하여 유의적인 차이는 없었으나 개엽 3단계에서 처리한 소나무의 일부에서 신초의 상단이 마르고 갈변하여 굽어지는 현상이 나타났다.

광합성율의 변화는 개엽 1단계와 개엽 2단계에서 처리한 경우, 처리 후 14일 경과시부터 일시적으로 감소하였으나 28일 경과하여 광합성율을 회복한 반면, 개엽 3단계 처리구에서의 광합성율은 처리 후 4일 경과 시부터 급격히 감소하여 처리 후 7~14일 경과 시 대조구의 22~27%로 낮을 값을 나타내었고 21일 경과 시에도 대조구의 48%로 완전히 회복하지 못하였다(Figure 1).

바닷물 살포 처리에 따른 광합성의 광화학계 및 탄소고정계 특성을 개엽 1단계 처리구는 처리 후 35일째, 개엽 2단계 처리구는 27일째, 개엽 3단계 처리구는 21일째 측정한 결과(Figure 2), 개엽 1단계와 개엽 2단계 처리에서는 대조구와 유의적 차이가 나타나지 않은 반면, 개엽 3단계 처리에서는 순양자수율과 탄소고정효율이 대조구의 60%, 39%로 감소하여 바닷물 살포로 인하여 광합성에서 빛에너지를 화학에너지로 변환시키는 광화학계의 활성 및 CO_2 고정계 효소인 Rubisco의 활성이 떨어진 것으로 판단된다. 모든 처리구의 엽록소 함량은 대조구와 비교하여 유의적 차이가 없어 바닷물 살포가 엽록소의 양에 미치는 영향보다는 광을 수확하는 엽록소의 질적 능력에 영향을 준 것으로 사료된다.

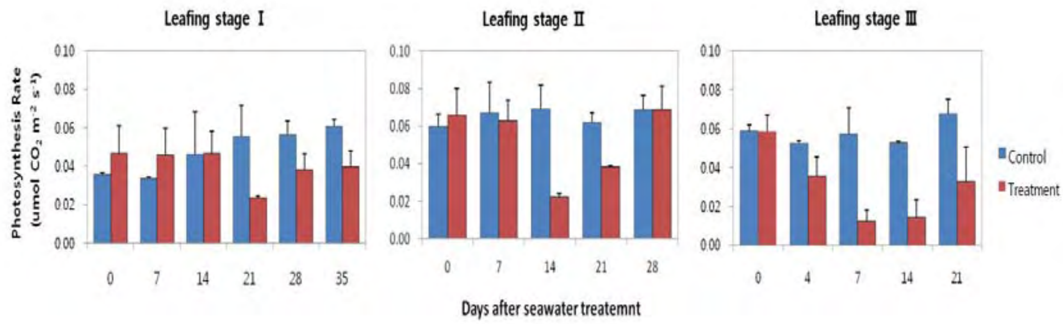

Figure 1. The change of photosynthetic rate at PPFD 1000 umol $CO_2\,m^{-2}\,s^{-1}$ in the leaves of *Pinus densiflora* for 35days after seawater treatment.

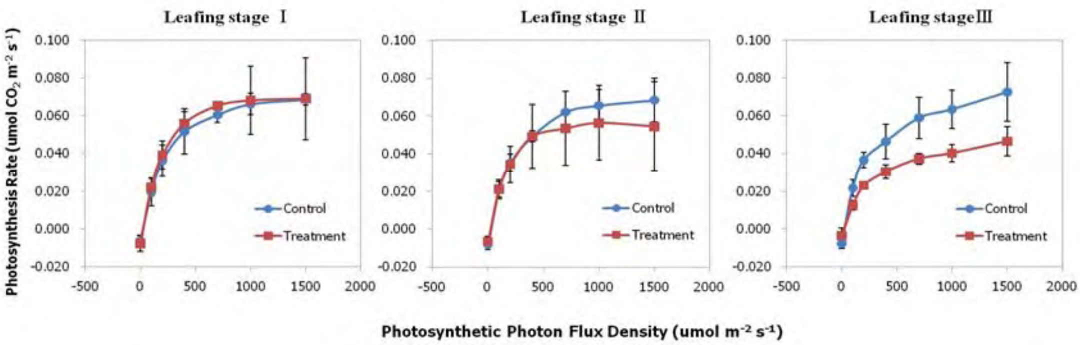

Figure 2. The light response curve of net photosynthetic rate in the leaves of *Pinus densiflora* at 35 days(leafing stage I), 28 days(leafing stage II), 21 days(leafing stage III) after seawater treatments.

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Effects of previous-fertilization treatment and fertilizer-induced stress on the growth and nutrient contents of *Chamaecyparis obtusa* seedlings

전년도 시비경험과 당년 시비스트레스가 편백 생장 및 양분함량에 미치는 영향

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Abstract

It is required to produce healthy seedlings for restoration of destroyed forest by forest fire. The purpose of this study is to investigate early plant growth and nutrient uptake response of *Chamaecyparis obtusa* seedlings to previous-fertilization treatment and fertilizer-induced stress during nursery production systems. In 2008, one year old of Chamaecyparis obtuse seedlings were supplied with a mixed nitrogen-phosphorus-potassium (N-P-K) fertilizer at the amount of 27.6 g m^{-2} N, 12.2 g m^{-2} P. After one year, showing similar growth of seedlings were selected and transplanted in the 30L pots. They were over-fertilized with Basacote® 80 g pot^{-1}. Plant growth of the none-fertilized plants in next year exhibited no differences as previous-fertilization treatment, whereas that of the over-fertilized plants which had experienced previous-fertilization treatment was better than the others. Carbohydrates distribution to belowground biomass was low at the over-fertilized seedlings regardless of previous-fertilization treatment. N and P concentration of leaf and root were irrelevant to previous-fertilization treatment. N and P content of tissues were high at the over-fertilized plants on the whole. This study proved that previous-fertilization treatment at nursery may increase tolerance to over-fertilization stress in the beginning of outplanting.

요약

산불지 초기 복원 성공을 위해서는 건전한 묘목 생산이 반드시 요구된다. 이 연구의 목적은 묘목 생산 단계에서 전년도 다른 시비경험과 당년 과시비 스트레스 처리가 편백의 초기 생장 및 양분흡수량에 미치는 영향을 구명하는 것이다. 산불지 초기 복원 성공을 위해서는 건전한 묘목 생산이 반드시 요구된다. 2008년 1-0묘 편백을 보성양묘사업소 포지에 심고 무처리(0 g m^{-2} N, 0 g m^{-2} P)와 27.6 g m^{-2} N, 12.2 g m^{-2} P 비료를 시비 처리하였다. 2009년 3월 말에 생장이 유사한 묘목을 선발한 후 30 L 화분에 식재하고, 대조인 무처리와 과시비 스트레스(지효성복합비료 바사코트 80 g pot^{-1})를 처리한 후 생장과 양분흡수량을 조사하였다. 시비스트레스 무처리에서는 전년도 포지 시비 경험에 따른 편백 묘목 생장에 차이가 없었지만, 시비스트레스 처리에서는 대조에 비해 전년도 시비경험이 수고 및 지상부 생장을 증가시켰다. 지하부로의 탄수화물 분배는 전년도 시비경험에 관계없이 시비스트레스 처리에서 낮았다. 잎과 뿌리의 질소와 인 농도는 전년도 시비경험에 의한 차이는 없었고, 시비스트레스 처리에서 질소와 인 함량이 대체적으로 높게 나타났다. 이 연구를 통하여 양묘장에서의 적절한 시비경험이 향후 현장에서 식재 시 수행하는 시비로 인한 시비스트레스를 줄일 수 있는 방법임을 알 수 있었다.

서론(Introduction)

묘포장에서 비료 경험에 대한 묘목의 생장 반응 및 산지 초기 생장은 Salifu와 Timmer(2003)에 의해 제시된 양분 공급에 따른 식물 생장, 조직 내 양분 량, 양분 농도의 관계를 나타내어 주는 개념적 모델로 그 효과를 알아 볼 수 있다. 또한 Imo와 Timmer(1992)는 nutrient loading을 통해 묘포장에서의 묘목 시비가 다양한 종류의 침엽수종(white spruce 등)의 체내에 축적된 양분을 산지 초기 생장과정에서 이용하여 묘목의 초기 활착률을 증가시켜 옮겨심기 성공률을 높여준다는 것을 밝혔다.

편백은 우리나라 남부지방의 대표적 조림 수종으로써 산지 식재시에 시비처리를 하는 데 이것이 생장에 도움을 줄 수도 있지만 과도한 시비로 인한 스트레스로도 작용을 할 수 있다. 따라서 본 연구에서는 전년도 시비 경험 유무에 따라 당년 과시비 스트레스 처리가 편백의 생장과 양분에 어떠한 영향을 미치는지 알아보고자 수행하였다. 이는 산불지 초기 복원을 위한 건전 묘목 생산에 있어서도, 포지에서의 시비 경험이 건전 묘목들이 산지에 옮겨 심어졌을 때 과도한 시비스트레스에 어떤 반응을 보이는지 알아보기 위함이다.

재료 및 방법(Methodology)

실험 수종인 1-0묘 편백을 2008년 1년 동안 보성양묘사업소 포지에 심고 무처리(0mg^{-2} N, 0mg^{-2} P)와 27.6g m^{-2} N, 12.2g m^{-2} P 비료를 처리하였다. 건전하며 균일한 묘목을 얻기 위하여 2009년 3월 말에 생장이 유사한 묘목을 각 처리별로 12본을 선발하였다. 선발된 묘목을 뿌리가 상하지 않도록 굴취하여 국립산림과학원 산림생산기술연구소로 옮긴 후, 화분에 심을 때까지 그늘진 곳에 가식한 후 충분히 관수하였다. 실험에 이용된 화분은 윗지름 36cm, 아래지름 26cm, 깊이 43cm 크기의 화분으로 화분 당 30L의 마사토를 이용하였다. 화분 토양에 과시비스트레스 환경을 만들어주기 위하여 대조인 무처리와 과시비 스트레스(지효성 복합비료 바사코트 80g pot^{-1})를 처리하였다.

가식 3일 후 선발된 묘목들을 화분에 옮겨 심고 온실(연평균 상대습도 61~77%, 온도 14.6~29℃)에서 관찰하였다. 계속적인 동일 위치의 근원경 측정을 위해 지상에서 1cm 위치에 흰페인트로 표시하여 그 곳을 연속 측정하였다. 식재 2주 후에 초기 생장을 측정하였고 굴취 전에 수고와 근원경을 다시 측정하였다. 2009년 10월 초에 뿌리가 손상되지 않도록 화분에서 묘목을 굴취한 후 흐르는 물에 토양을 씻어준 후 65℃ 항온기에서 건조시켰다. 1주일 후 지상부와 지하부로 나누어 건중량을 측정하고 뿌리와 잎의 양분분석을 실시하였다. 실험 데이터는 SAS 9.2를 이용하여 분산분석을 실행하여 유의성을 살펴 보았다.

결과 및 고찰(Results and Discussion)

2009년도에 시비 스트레스를 처리해 주지 않은 화분 토양에서 편백의 수고 생장은 전년도 포지에서의 시비 경험에 따른 차이가 없었지만, 시비 스트레스 처리 화분 토양에서는 전년도 시비 경험이 있는 편백의 수고 생장이 더 좋게 나타났고, 근원경에서는 전년도 시비 경험에 따른 유의한 차이를 발견할 수 없었다. 2009년도 처리에 따른 수고 생장율은 무처리에서 13%, 과시비 스트레스 처리에서 29%로, 약 2배 이상의 생장율 차이를 보였다.

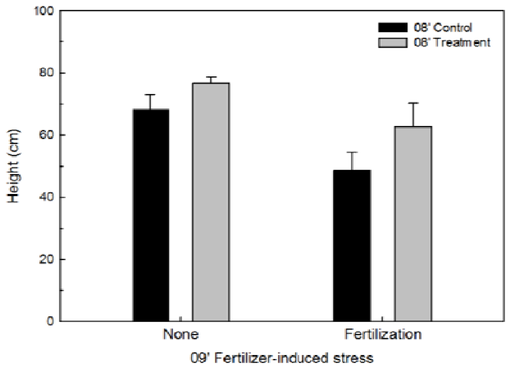

Figure 1. Height after inducing fertilizer stress. Vertical bars are standard errors of mean(n=6).

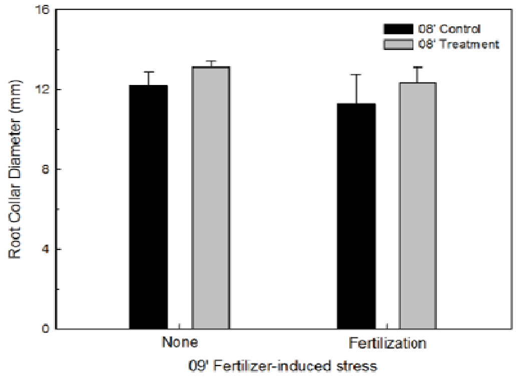

Figure 2. Root collar diameter after inducing fertilizer stress. Vertical bars are standard errors of mean(n=6).

지상부와 뿌리의 건중량은 2009년도에 과시비 스트레스 환경을 만들어 준 토양에서 전년도에 시비 경험이 있던 편백의 지상부로 물질 축적량이 무처리보다 많았다. 또한 뿌리 건중량은 2009년도에 과시비 스트레스 환경을 만들어 준 토양에서 뿌리 발달을 저하시켜 무시비 환경보다 바이오매스 축적량은 적게 나타나지만, 과시비 스트레스 처리에서 전년도에 시비 경험이 있던 편백의 뿌리 건중량이 시비 경험이 없던 것 보다 더 많음을 볼 수 있다. Quoreshi와 Timmer(2000)에 따르면 지수적 시비(exponential fertilization)는 식물의 양분 요구가 낮은 수준인 기간 동안 체내에 염분 축적 가능성을 줄여줌으로써 시비양이 식물의 요구에 부합하기 때문에, 과시비로 인한 뿌리 손상 피해를 최소화시키는 것을 도울 수 있다는 이론으로 설명될 수 있다.

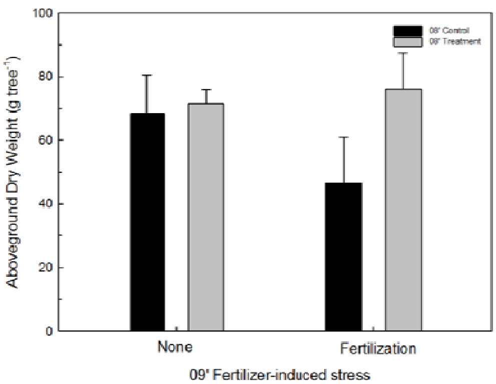

Figure 3. Aboveground dry weight after inducing fertilizer stress. Vertical bars are standard errors of mean(n=6).

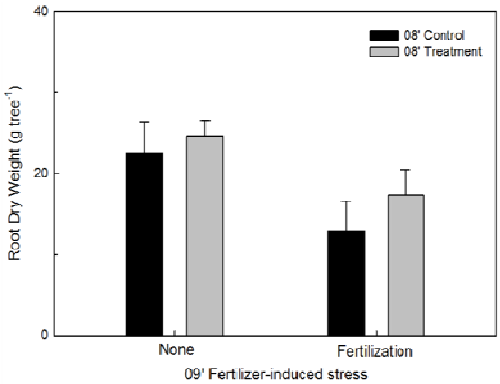

Figure 4. Root dry weight after inducing fertilizer stress. Vertical bars are standard errors of mean(n=6).

잎과 뿌리에서 질소와 인의 농도는 전년도 시비 경험에 의한 유의한 차이가 보이지 않았고, 시비 스트레스 처리에서 질소와 인의 함량이 대체적으로 높았는데, 질소의 함량은 유의한 차이를 보이지 않았다. 하지만 2008년도에 시비를 경험하지 않고 2009년도에 과시비 스트레스 처리를 해 준 화분에서 자란 편백 뿌리에서 인의 체내 농도가 유의하게 높았는데, 이것은 발근에 관여하는 인이 양분 흡수를 위한 뿌리 발달을 위해 뿌리에 분포하는 비율이 높은 것이거나 흡수에 비해 낮은 생장율로 인하여 단위무게당 농도는 증가한 것일 수도 있다.

Table 1. Nutrient concentrations(g kg^{-1}) of leaf and root after inducing fertilizer stress. Standard errors are in parenthesis(n=6).

Elements	fertilizer-induced stress	**None**		**Fertilization**	
	previous-fertilization treatment	Control	Treatment	Control	Treatment
Leaf					
N		11.2(2.1)	10.4(0.9)	12.3(1.6)	12.2(1.2)
P		1.7(0.1)	1.8(0.1)	1.6(0.2)	1.9(0.2)
Root					
N		8.7(1.3)	8.4(1.0)	13.3(3.2)	10.9(1.6)
P		1.9(0.3)	2.0(0.2)	3.2(0.4)	2.3(0.5)

이처럼 묘포장에서 시비를 경험한 편백 묘목들이 산지에서 과시비 스트레스를 받을 경우 그것에 대한 내성을 가짐으로써 시비를 경험하지 않은 묘목들보다 수고 성장이 더 좋고, 뿌리 손상이 적으며 바이오매스 축적량 비율이 높은 것을 알 수 있다. 즉, 묘포장에서 시비를 경험한 묘목들이 시비를 경험하지 않은 것들보다 시비 경험에 의한 내성으로 인하여 과시비 스트레스에 더 잘 대응하여 산지 식재 성공률을 높이는 방법이고 이는 산불지 초기 복원에 필요한 건전 묘목을 생산할 수 있는 유용한 방법임을 이번 연구를 통해 알 수 있었다.

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Dynamics of Advanced Seedlings of *Pinus koraiensis* in three Stand Types

세가지 임분 유형에서 잣나무 전생치수의 동태

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Abstract

This study was conducted to investigate the dynamics of advanced seedlings on different stand types to understand potential of natural regeneration and to consider applicable possibility of intensively managing technique to promote natural regeneration of *Pinus koraiensis* in Korea. The study site was classified into three stand types; thinned, about 30 years old Korean white pine plantation(stand type A), thinned, about 50 years old plantation (stand type B), and non-thinned about 50 years old plantation(stand type C). The stand types showed different stand and environment characteristics by stem density, species composition and stand development. In summer 2005, the beginning of this study, investigated seedlings of Korean white pine were 2,125, 18,650 and 55,725 individuals / ha in stand type A, B and C, respectively. The ratios of generation and death of advanced seedlings were 0.81 and 0.38, 0.62 and 0.49, and 0.33 and 0.84 in stand type A, B and C, respectively. Density and annual growth of survived seedlings during investigated period were 1,200 and 0.06, 10,600 and 0.20, and 10,625 individuals / ha and 0.02mm / yr in stand type A, B and C, respectively.

요 약

한국 잣나무림에서의 잣나무 천연갱신 가능성을 타진하고자 간벌되었던 30년생 잣나무 조림지(임분 유형 A), 50년생 잣나무 조림지(임분 유형 B), 그리고 전혀 간벌되지 않았던 50년생 잣나무 조림지(임분 유형 C)등 3개의 임분 유형에서 갱신치수 밀도와 동태를 파악하였다. 임분들은 간벌처리의 유무와 임령에 따라 임목밀도, 수종구성, 그리고 식생 발달에 있어 각각 다른 구조와 환경특성으로 보였다. 이 연구가 시작된 2005년 여름에 조사된 갱신치수는 임

분 유형 A, B, C에서 각각 ha당 2,125, 18,650, 55,725개체였다(간벌되지 않은 지역의 밀도가 매우 높았음). 갱신율과 고사율은 임분 유형 A에서 0.81과 0.38, 임분 유형 B에서 0.62와 0.49, 그리고 임분 유형 C에서 0.33과 0.84였다. 전체 조사기간 동안 생존한 갱신치수의 밀도와 1년간 생장량은 임분 유형 A, B, C별로 각각 1,200개체/ha와 0.06mm, 10,600개체/ha와 0.20mm, 그리고 10,625개체/ha와 0.02mm로 조사되었다.

Keyword : *잣나무(Pinus koraiensis), 갱신, 생물다양성 연구*

서론(Introduction)

잣나무의 자연적인 분포지는 일본의 일부 지역부터 한국, 중국 북동부, 러시아 시베리아 지역이지만, 한국에서는 일제시대와 치산녹화시기에 제주도를 제외한 남한 지역에 주요 조림수종으로 식재되어 왔다. 남한 지역에 잣나무 조림지의 면적은 340천ha로 전체 조림지 면적의 약 19%를 차지하고 있다. 잣나무 조림지에서의 천연갱신은 매우 어렵다는 것이 일반적인 이해이지만, 주변 활엽수림에서의 자연적인 치수 발생은 모수림과의 거리와 비례하여 풍부한 것으로 파악되고 있으며, 잣나무 조림지에서도 간벌 등 밀도 변화 이후에 풍부한 치수발생이 관찰되고 있다. 따라서 잣나무 조림지의 임분 구조에 따라 잣나무 천연갱신 가능성이 다를 것으로 판단되며, 이를 구명하여 잣나무 천연갱신을 촉진할 수 있는 집약적인 산림관리 기술의 적용가능성을 고찰하는 것이 이 연구의 목적이다.

재료 및 방법(Methodology)

연구지는 여러 간벌처리에 의해 인공림의 생물다양성 및 생태계 변화 과정을 파악하고, 생태적 관리 기법을 개발하고자 선정된 춘천 인공림과 생물다양성 연구지에서 수행되었으며, 간벌처리가 실연되기 전인 2005년 여름, 2005년 가을, 2006년 봄, 2006년 여름까지의 조사자료를 기반으로 하였다. 대상지의 잣나무 조림지는 간벌되었던 30년생 잣나무 조림지(임분 유형 A), 50년생 잣나무 조림지(임분 유형 B), 그리고 전혀 간벌되지 않았던 50년생 잣나무 조림지(임분 유형 C)등 3개 임분 유형으로 구분되며, 각 임분 유형은 다른 구조적, 환경적 특성을 보였다(Table 1). 각각의 임분 유형별로 5m x 5m 크기의 조

사구를 각각 16개씩을 설치하였으며, 치수의 밀도와 발생 및 고사 등 동태를 모니터링하였다.

Table 1. Site conditions of stand types in the study area.

Stand Types	Topography & Environmental features									
	Aspects	Altitude (m)	Slope (°)	Canopy Closure (%)	Floor closure (%)	Mean LAI	Mean Temp. (°)	Mean Humid. (%)	Soil moist. (%)	Relative Illum. (%)
A	W	438~505	26	82	79	3.53	9.3	73	20.4	6.3
B	W	403~427	24	78	89	3.06	9.6	74	18.6	15.2
C	NW, W	329~400	25	89	13	3.26	9.5	75	14.5	6.1

결과 및 고찰(Results and Discussion)

2005년 여름, 연구 초기에 잣나무 치수 밀도는 A 임분 유형이 2,125개체/ha, B 임분유형이 18,650개체/ha, C 임분 유형이 55,725개체/ha로 50년생 임분에 비해 30년생 임분의 밀도가 극히 낮았다(Figure 1). 1년간의 밀도 변화는 간벌이 수행되었던 A와 B 임분 유형에서는 각각 44%와 7%가 증가하였으나, 간벌이 수행되지 않았던 C 임분유형은 51% 감소하였다. 갱신치수의 1년간 발생율은 A 임분 유형 81%, B 임분 유형 38%, C 임분 유형 62%인데 반해 고사율은 각각 49%, 33%, 84%였으며, 1년간 생존한 잣나무 치수는 1,200, 10,600, 10,625개체/ha였다. 잣나무 조림지의 임분 유형별로 갱신치수의 밀도, 발생, 고사 등은 임령과 간벌 유무 등에 의해 기인된 임분구조와 환경 요인에 영향을 받는 것으로 판단되며(Johnstone, 1981), 특히, 간벌처리 등 임분 밀도 조절이 갱신치수 생육에 영향을 미쳐 1년 이내의 초기 고사를 방지하는 데 효과적일 것으로 판단된다.

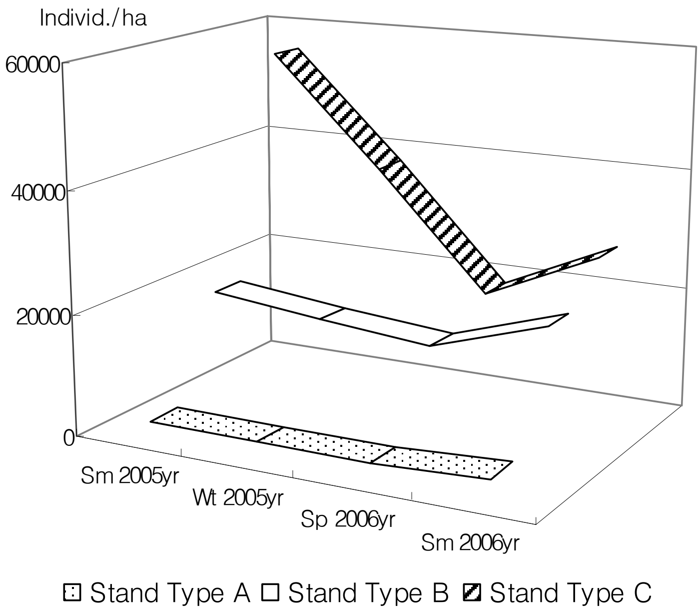

Figure 1. Change on abundance of *Pinus koraiensis* seedlings in three stand types

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Synersistic effects of a landslide risk in forest fire damaged area of Namwon city using aerial photographs

항공사진을 이용한 전북 남원시 산불피해지의 산사태 위험도 상승효과 분석

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Abstract

This study was conducted to know how much increase a landslide risk caused by forest fire. The object area is forest fire damaged area in Namwon city, Jeonbuk province. A landslide risk before forest fire damage was based on the landslide hazard map of Korea Forest Service. A landslide risk after forest fire damage was analyzed by extracting landslides occurred in 2010 from aerial photographs. Synergistic effect a landslide risk in forest fire damage area was appeared to about 32% by the accuracy of the landslide hazard map showed to researches.

요약

전북 남원의 산불피해지에서 발생한 산사태지역을 대상으로 산불피해 이전의 산사태 위험도와 산불피해 이후의 산사태 위험도의 차이를 분석하였다. 산불피해 이전의 산사태 위험도는 산림청에서 제공하는 산사태위험지도에서 추출하였으며, 산불피해 이후의 산사태 위험도는 2010년 발생한 산지토사재해 구역을 항공사진에서 추출하여 구하였다. 기존연구에서 나타난 산사태 위험지도의 정확도를 기준으로 산불피해지의 산사태 위험도 상승효과는 약 32% 증가하는 것으로 나타났다.

서론(Introduction)

일반적으로 여름철 태풍 및 집중호우시 발생하는 산사태는 산불피해지에서 일반산지에서보다 발생확률이 높은 것으로 알려졌다. 이것은 산불로 인해 산지에 존재하는 산림이 훼손되고 토양의 점착성이 떨어져 토양의 유실이 급속하게 진행되기 때문이다(박경 등, 2009). 산불로 인하여 토사침식과 동시에 산사태 발생이 얼마나 증가할 것인지에 대한 정량화가 필요하다. 현재까지 산사태 위험도를 판단할 수 있는 대표적인 기준으로 산사태 위험지 판정표가 있다(최경, 1998). 산사태 위험지 판정표에 제시된 인자 중 임상이 산불피해지를 반영할 수 있는 부분이지만 대부분 임상과 영급으로 분류되어 있어 적용이 쉽지않다. 따라서 본 연구에서는 2005년 대형산불이 발생한 전북 남원시 산동면의 산불피해지를 대상으로 2010년 발생한 산지토사재해[74] 공간자료와 산림청의 산사태 위험지도를 이용하여 산불피해시 나타나는 산사태 위험도의 상승효과를 분석하였다.

방법(Methodology)

전북 남원시 산동면 일대를 2010년 9월 항공사진을 촬영하여 정사보정을 거쳐 단일 모자이크 영상을 제작하고, 육안판독에 의해 산지토사재해 발생구역을 추출하였다(Figure 1).

Figure 1. Aerial photographs after landslide occurrence in September 2010 and landslide hazard map of Korea Forest Service (White line of central image means the landslide zones)

[74] 산지토사재해는 산사태와 토석류 등을 총칭함.

추출한 산사태 공간자료를 이용하여 산불피해지와 일반산지에서 발생한 산사태면적을 각각 산출하였으며 산사태 위험지도와 중첩하여 1, 2등급지의 비율을 산출하였다.

결과 및 고찰(Results and Discussion)

산림청 통계자료를 이용하여 이 지역에 발생한 산지토사재해를 분석한 결과 남원시 일대에서 2010년 8월 13~18일까지 국지성 집중호우로 인해 약 40ha의 산지토사재해가 발생하였는데, 이 중 산불피해지에서 약 18ha가 발생하였다. 즉, 전체 산지토사재해 피해 중 약 45%가 산불피해지역에서 발생한 것으로 나타났다. 이것을 일반산지과 산불피해지로 구분하여 산지토사재해 발생면적을 각 면적으로 나누어 단순 발생비율을 산출해보면 일반산지는 0.05%, 산불피해지는 10%로 일반산림 대비 산불피해지의 산지토사재해 발생비율이 200배 높아진다(Figure 2). 이중 2005년 대형 산불이 발생했던 산동면 목동리 일대에서는 산지토사재해가 남원시 전체의 17%, 전체 산불피해지의 약 39%가 발생하였다. 여기서 항공사진을 이용하여 산지토사재해의 실제 발생면적을 분석한 결과 산림청 집계면적보다 약 두 배 많은 12.5ha로 나타났다.

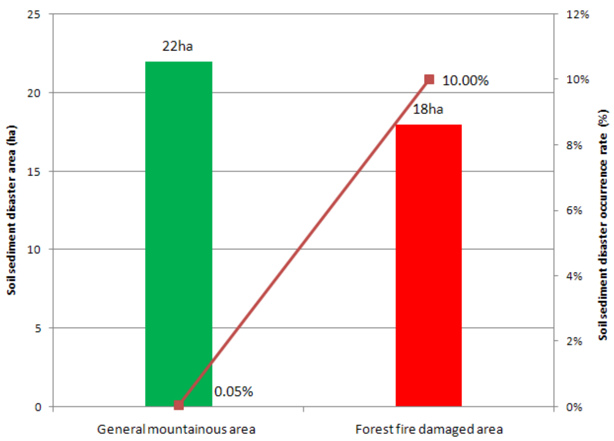

Figure 2. The area of soil sediment disaster and occurrence rate through comparing with general mountainous area and forest fire damaged area

Figure 3의 (a)와 같이 산림청 산사태 위험지도와 남원지역의 산사태 공간자료를 이용하여 산사태 발생위치에서의 산사태 위험지도의 등급분포를 알아보았으며 기존에 같은 방법으로 연구된 전북 무주·진안·장수지역과 강원 평

창지역의 결과와 비교하였다(Woo et al., 2008; Youn et al., 2009).

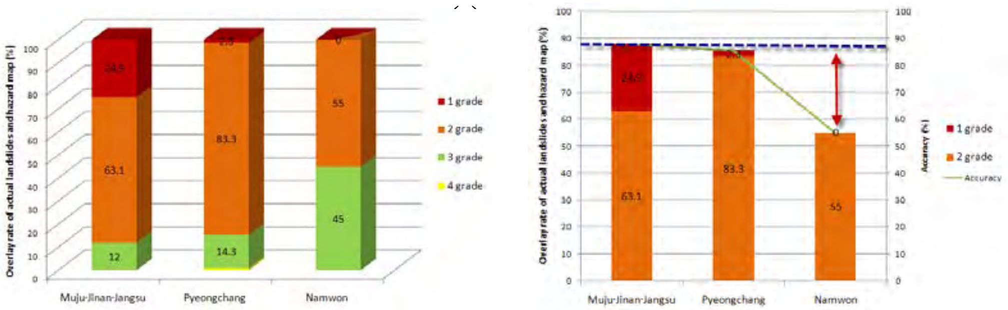

Figure 3. (a) Overlay rate of hazard map and actual landslides of three areas occurred in the 2000s (b) Synergistic effect of a landslide risk in Namwon using average accuracy of hazard map in two areas(except Namwon)

전북 무주·진안·장수지역과 강원 평창지역은 산불피해지가 아닌 일반산지에서 발생한 산사태로 남원의 산불피해지에서 발생한 산사태와는 특성이 다르다. 또한 산사태 위험지도는 산불로 인해 변화된 상황을 반영할 수 없어 남원 산불피해지와 직접 비교하기는 어렵다. 그러나 산불피해지보다 위험도가 낮은 일반산지에서 나타난 산사태 위험지도의 정확도[75]를 최소 위험도로 가정하여 실제 발생한 산사태 공간자료와 산사태 위험지도를 등급분포를 분석하였다. Figure 3의 (a)에서 남원 산불피해지역은 산사태 위험 1등급이 없고 대부분 2, 3등급이 분포하고 있어 산사태 위험지도의 정확도는 55%로 나타났다. 그러나 (b)에서와 같이 다른 두 지역과 같은 분포를 갖을 경우, 즉 산불피해로 산사태 위험도가 증가하여 현재의 2, 3등급이 1, 2등급으로 상승하여 평균 정확도 87%에 가까워진다면 산사태 위험도 상승효과는 약 32%가 증가하는 것으로 판단할 수 있다.

산불피해에 의한 산사태 위험 상승효과를 더욱 정확히 알기 위해서는 실제 산불지역에서 발생한 산사태를 조사하여 산불피해지에 대한 산사태 위험도 판정방법이 연구되어야 한다. 그리고 이를 바탕으로 제작된 위험지도를 이용하여 기존의 산사태 위험지도와의 비교를 통해 분석되어야 한다. 본 연구는 이러한 연구를 시작하기 위한 기초 연구이며 향후 앞서 언급한 것같이 산불피해지를 위한 맞춤형 산사태 위험지도를 개발하도록 노력할 것이다.

[75] 산사태 발생위치에 나타난 산사태 위험지도 1, 2 등급 비율

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Estimation on Forest Fire Potential Hazard by Fuel Load Change of Forest Strata in Forest Stand

산림내 층위별 연료량 변화와 임내 산불잠재위험성 평가

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Abstract

This study performed a field survey of pine forest and oak kind (*Quercus acutissima* and *Quercus variabilis*) broadleaf forest in southern Chung-Nam Province (including Daejeon), Gongju, Yesan and Cheongyang. Upper trees in southern Chung-Nam province indicated that ground fuel loads of pine trees stand including bark, stem xylem, live branches and leaves ranges from 7.11 ton/ha to 255.21 ton/ha, which accounts for 58.5% to 90.9% in each part of fuel loads that contribute to upper class fuel loads out of total amount. Oak trees also demonstrated similar fuel loads and proportions, which are 10.7~221.02 ton/ha and 69.0~95.1% on upper class, and 0.82~4.19 ton/ha and 0.5~1.9% on middle class respectively. Three parameters (fuel moisture content (FMC), height to the live crown base (CBH) and surface fire intensity (SFI)) were calculated for potential risk estimation on stands on the condition of that fire spreads successfully from surface to crown. These parameters were introduced for assessment of potential fire risk by estimating critical surface fire intensity (CSI), which determines crown fire transition.

요약

산림내 산불잠재위험성 평가를 위해 충남지역을 대상으로 소나무림과 참나무림의 층위별 연소물량의 분포를 추정하기 위하여 각 임분의 층위별 연소물량을 10m×10m 방형구내의 상층(수고 8m 이상), 중층(8m 이하), 관목층, 지표층(초본, 낙엽, 낙지)을 대상으로 총 36개소를 조사하였다. 조사결과를 이

용하여 단위면적당(ha) 바이오매스량(연소물량)을 추정하였다. 혼효림의 층위별 연소물량은 소나무림과 참나무림에서 얻어진 결과를 1/2씩 합산하여 추정하였다. 분석결과 충남지역 소나무 임분의 지상부 연소물량 중 수피를 포함한 줄기목질부, 생지부, 생엽부를 모두 합친 상층의 연료량은 7.11~255.21 ton/ha로서 각각의 총량 중 58.5~90.9%를 차지하였고 영급이 증가할수록 상층 연소물량이 증가하는 경향을 나타내었다. 참나무 임분의 상층 연료량은 10.7~221.02 ton/ha로서 각각의 총량 중 69.0~95.1%를 차지하였다. 본 연구결과에서 얻어진 층위별 연소물량의 공간분포를 이용하여 충남지역의 임내의 잠재위험성 평가를 위해 지표화에서 수관화로 전이되는 조건으로 연료습도(FMC), 지하고(CBH), 지표화 강도(SFI) 등 3가지 파라미터를 산출하여, 수관화 전이를 결정하는 지표화 강도(CSI)를 추정하여 연료량 변화에 따른 임내 산불잠재위험성을 평가하였다

Introduction

Fire behavior and fire severity are determined by characteristics and vertical and horizontal continuity of diverse fuel level, and fire danger on a particular stand affects on fire behaviour based on potential amount of fuel (Russel et al., 2004). Fuelbed strata has various representation of combustion environment, fire spread rate and fire impact. In addition, crown layer, ladder fuels and shrub layer impact on crown fire, and herb layer, surface fuel and woody fuels have an effect on surface fire (Snadberg and others 2001). There is a limitation of fire potential danger assessment on the basis of a single method for preparation and correspondence of yearly repeated fires. Therefore, this study performed an estimation of burning quantity on each layer of pine and oak forest in Chung-Nam, South Korea by using 4th digital forest type map and field survey data. Then, performance of fuel load map production about upper, middle, shrub and surface layer in the forest was carried out to estimate the fire risk.

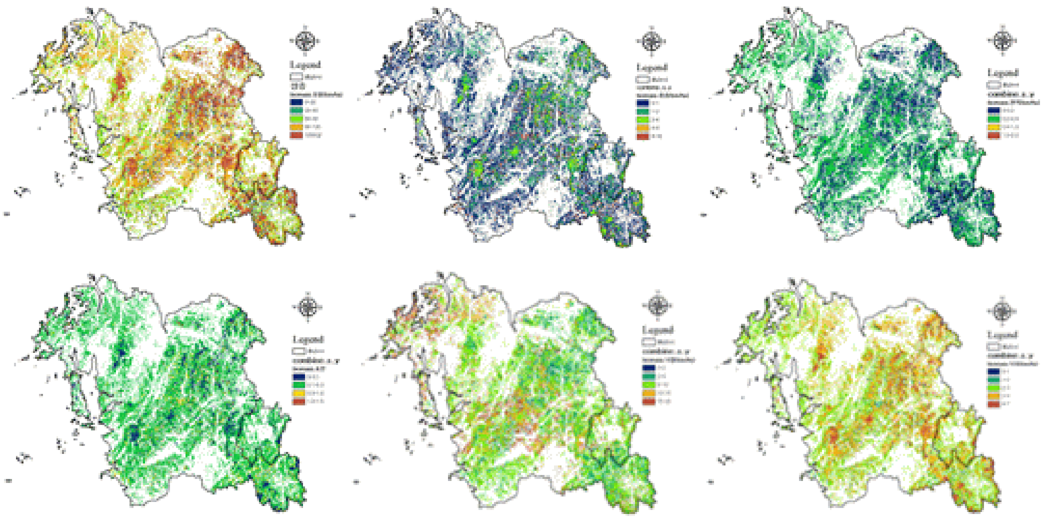
Materials and Mehtods

This study performed a field survey of pine forest and oak kind (*Quercus acutissima* and *Quercus variabilis*) broadleaf forest in southern Chung-Nam Province (including Daejeon), Gongju, Yesan and Cheongyang. Fossil-wood survey was introduced in pine forest and broadleaf forest (*Quercus mongolica* and *Quercus variabilis*), which covers 3 plots in each age class (Ⅰ-Ⅵ) (36 plots in total) with 10m×10m plot size as the two forest types show similar characteristic of stand in each age class. Diameter at the breast height (root-collar caliper for under age class 2), age of trees, tree height and number of trees in a plot are measured on ground section (upper, middle tree) in each plot. Middle trees were cut down at the closest ground height to measure tree height and fresh weight (weight of fuel). In order to estimate surface fuel load, fresh weight measuring was conducted. It includes shrub, herb, fallen leaves and branches on existing pine and broadleaf tree stand. Size of square plots were designed as 2m×2m for shrub layer and 0.5m×0.5m for herb, fallen leaves and branches at average area 3 repeated times. After every specimen was cut and measured, fresh weight was measured in the field. Among selected specimens, one third were separated and packed to deliver to laboratory. They were dried in a dry oven until specimen temperature reached 85℃. Then, dry weight calculation was conducted at the laboratory with the utilization of two variables (tree height and diameter at the breast height) to estimate upper tree fuel load. The calculation employed The Wood Resource Assessment Program (Korea Forest Research Institute, 2004), which was developed by Korea Forest Research Institute. On the basis of dry weight (fuel load) calculation in each layer on the quadrat, amount of biomass estimation per unit area was performed. Finally, this field survey was introduced to the ArcGIS 9.3 program for building up a spatial data set. This procedure took advantage of the fuel load according to structure of the stand in each layer, which is based on classification of coniferous forests, broadleaf forests and mixed forests in each age class from the 4th digital forest type map. In addition, the data set evaluates fire potential risk based on Van Wagner's (1977) Crown Fire Theory.

Results and Discussion

1. Fuel load of stand in each layer as age class changes

Upper trees in southern Chung-Nam province indicated that ground fuel loads of pine trees stand including bark, stem xylem, live branches and leaves ranges from 7.11 ton/ha to 255.21 ton/ha, which accounts for 58.5% to 90.9% in each part of fuel loads that contribute to upper class fuel loads out of total amount. It demonstrates that the fuel loads increased as age class increased. Also, middle class trees represented an increase of fuel loads as age class increased. The fuel loads were between 0.55 ton/ha and 3.53 ton/ha, which accounts for 0.53~3.53% of the total amount. On the other hand, a shrub layer fuel loads change as age class increased mostly indicated opposite to the other classes. Shrub layer fuel loads ranged from 0.06 to 1.91 ton/ha, which comprises between 0.1 and 15.7% from total ground fuel loads. Surface layer, which includes a herb, leaves and fallen leaves and branches, showed fuel loads 0.04~1.12 ton/ha, 1.11~17.92 ton/ha and 0.91~6.99 ton/ha respectively. Each of them accounts for 0.01~9.2%, 6.1~15.8 and 1.3~7.5%. The result of shrub layer represents that fuel loads of herb decreased as the age class increased, while fallen leaves and branches increased fuel loads at the same condition. Oak trees also demonstrated similar fuel loads and proportions, which are 10.7~221.02 ton/ha and 69.0~95.1% on upper class, and 0.82~4.19 ton/ha and 0.5~1.9% on middle class respectively. The same trend as the shrub layer in the pine trees occurred. Fuel loads ranged from 0.14 to 0.35 ton/ha, which accounts for 0.1~1.6%, with fluctuation of fuel loads. Relative proportions of herb (0.05~1.15 ton/ha), fallen leaves (2.95~6.64 ton/ha) and branches (0.32~6.81 ton/ha) fuel loads out of total ground fuel loads, were 0.02~7.7, 2.2~19.6% and 20.~3.1% respectively. The oak trees showed a tendency towards decrease of herb fuel loads and increase of fallen leaves and branches fuel loads as the age class increased.



2. Estimation of potential fire risk on stands from fuel loads change

In general, intense surface fires play a role in drying upper class fuel (Alexander 1998) and crown fuels (referred to as canopy fuels, or aerial fuels) imply hanging fuels (vine, moss, live leaf, branch etc) on trees. These fuels are mostly fine or live fuels, which are less than 0.25 inch. Crown fuel is a biomass necessary for crown fire that can spread on to shrubs and trees in lower classes or to other crowns. Shrub/small tree stratum provides continuity of fire from surface fuel to crown fuel, which eventually impacts on crown fire as ladder fuels and as it enhances intensity of fire. Three parameters (fuel moisture content (FMC), height to the live crown base (CBH) and surface fire intensity (SFI)) were calculated for potential risk estimation on stands on the condition of that fire spreads successfully from surface to crown. These parameters were introduced for assessment of potential fire risk by estimating critical surface fire intensity (CSI), which determines crown fire transition. A support theory for the assessment is that crown fire transition can be predictable when SFI is higher than CSI or remains to only surface fire when SFI is equal or lower than CSI. A formula for the theory is described below:

$$CSI = 0.001 \times CBH^{1.5} \times (460+25.9\times FMC)^{1.5}$$

Where, CSI = critical surface fire intensity required for crowning (KW/m),
CBH = height to the live crown base (m), and
FMC = foliar moisture content (%).

A spatial composition of CBH and surface layer (fallen leaves and branches, herbaceous layer) fuel loads in southern Chung-Nam province is described in Figure 2. As can be seen in Figure 3, the figure describes changes of CSI in response to FMC and CBH changes. It reveals that a higher CSI figure is required for the successful transition from surface fire to crown fire when CBH increases. Moreover, crown transition CSI estimation result is described Figure 4, which is about a spatial distribution when we assume that crown fuel moisture content is 50%, which represents that it is suitable for spring dry period moisture content. Based on Figure 4, it is suggested that potential fire risk should be reduced before the crown transition occurs by performing activities such as thinning, pruning and elimination of lower class fuel when CSI figure is low, which possibly results in faster crown transition process. In addition, verification process will be performed with potential fire risk assessment result by using amount of heat release data in each part of wood, which is obtained for experimental purposes, and the spatial distribution of fuel loads in each class, which is acquired by this study in the future.

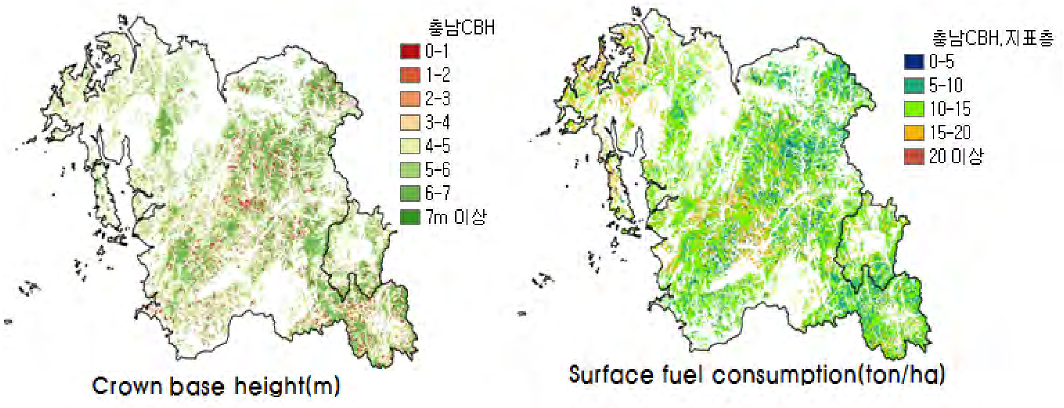


Fig. 2. (left) CBH and (right) distribution of surface fuel loads in southern Chung-Nam province

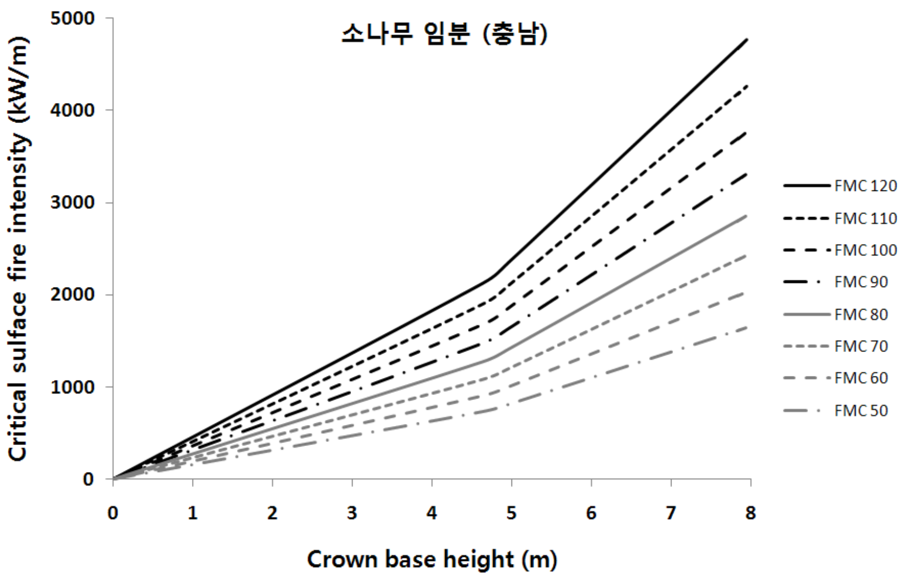


Fig. 3. CSI figure as CBH of pine tree stand changes in southern Chung-Nam province

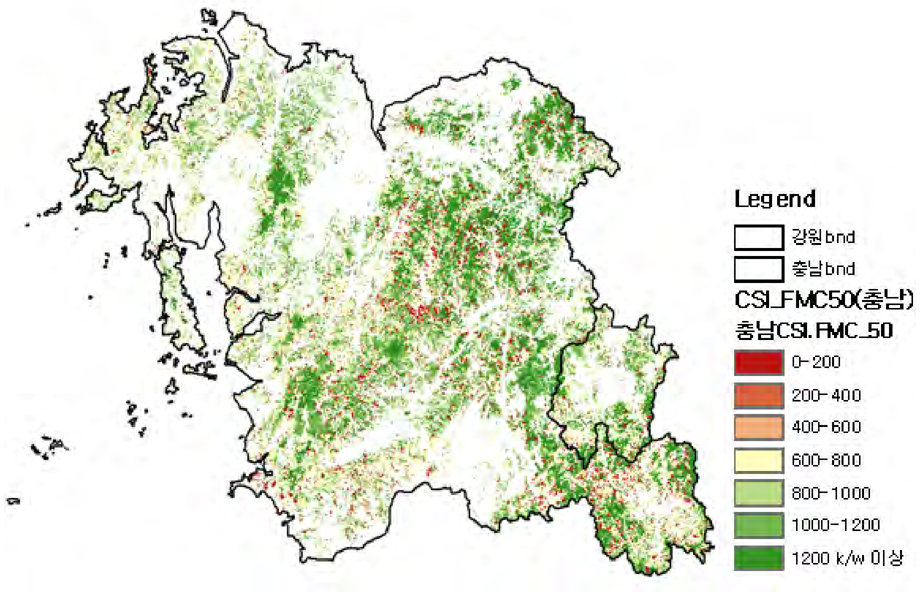


Fig. 4. CSI distribution in southern Chung-Nam province when crown fuel moisture content is 50

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Analysis of spatial distribution for forest fire damaged areas in East-coast of Gangwon province

강원도 동해안 산불피해 지역의 공간분포 분석

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Abstract

Forest fires have been threatened to natural resources, endangered species, properties and even to human lives. Efficient management of forest fires requires a complete understanding of the environmental and human related activities, as well as complicate spatial relationships among them. And understanding the impact of fire requires detailed knowledge about where fires occur, how they alter landscape patterns and precise calculations of fire regime parameter. In this work, a reconstruction of the perimeters of fires that occurred during 1996-2005 was made by means of aerial photographs, forest cover type map aided by field inspection in study area located in East-coast of Gangwon province. Therefore, this study is to provide and classify the terrain, forest cover type, topographical factors, and to analyze spatial distribution for forest fire areas by applying the GIS/RS technology.

요약

산불의 효율적인 관리를 위해서는 산불발생에 영향을 미치는 인자와 이들 사이에서 발생하는 복잡한 공간적 관계에 대한 상세한 정보가 요구된다. 본 연구는 1996-2005년 동안에 발생한 강원도 동해안 산불피해지의 공간적 특성을 정량화하고 산림재해에 대한 기초자료를 제공하기 위하여 수행되었다. 대부분의 산불피해지는 고도 100m 이하, 경사도는 20-30°에서 가장 큰 면적 분포를 보이는 것으로 나타났으며, 소나무림 Ⅱ영급에서 가장 큰 피해면적을 보였다. 동해안 산불피해지는 임분구조, 지형과 기후조건 그리고 특히 가파른 지형에 상당히 민감한 특성을 보이는 것으로 나타났다.

Introduction

Massive forest fires have caused considerable environmental damage and adversely affected the social, economic and cultural aspects of forest sustainability Forest fire may profoundly alter the structure of the landscape (Dansereau and Bergeron, 1993). Landscape patterns can affect ecological processes (Turner, 1989), among others, the spread of disturbances (Turner et al., 1989), and, in particular, of fire. Consequently, much of the attention has focused in understanding the interactions between landscape patterns and fire since, ultimately, fire occurrence may be strongly linked to such patterns (Davis and Burrows, 1994). Mapping past fires is only possible through reconstruction based on aerial photography or other remote sensing procedure. It has been shown that, depending on the source of ignition, fires may occur in different places, and affect different types of vegetation (Vazquez and Moreno, 1998a). A prefferd occurrence of fire on certain locations within a given landscape means that average figures of fire regime parameters would be misleading, since some areas will burn more frequently than others. Knowing this is important for management, both in terms of risk evaluation and in terms of the consequences for the ecosystem. Therefore, understanding the ultimate role of fire requires that we know what patterns it creates, particularly with regard to the spatial distribution of burned areas, as these may affect future fire propagation, and also of where fires actually occur. Mapping fires, and determining the relationships between topographic features or other characteristics of the terrain and burned areas is important to evaluate the impacts of fire. The objective of this work is to map the fires that occurred in an area of East-coast in Gangwon province and determine where fires actually occurred in relation to topographic features (elevation, slope, aspect) or other characteristics of the terrain.

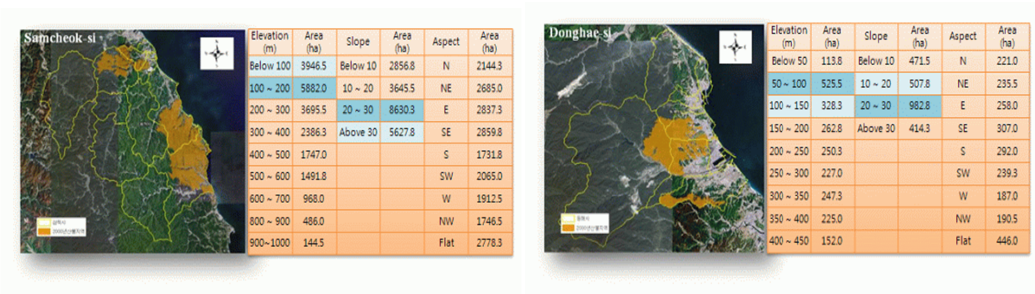
Material and Methodology

We used the FGIS information of all fires that occurred during the period 1996-2005 in forest fire damaged areas, Sokcho-si(2004), Gangneung-si(2000, 2004), Samcheok-si(2000), Yangyang-gun(2005), Donghae-si(2000), Goseong-gun(1996, 2000) of Gangwon province. In order to analyze the areas affected by fires as a function of their topographic attributes, we constructed a digital elevation model (DEM) of this burned areas. We digitized the elevation lines at 50-100 meter intervals from a 1:25,000 topographic map from this burned areas. The resulting vector files were rasterized to an image. From this image, and by means of interpolations, we obtained the DEM from which, once filtered, we derived the corresponding layers of elevation, slope, aspect.

Results and Discussion

Topographic features of forest fire damaged areas

Burned areas were not distributed proportionately to the available areas of forest territory according to their topographic features. Most of damaged area was much bigger at lower elevations (below 100m), at steep slope-angles (from 20 to 30°), and at various aspects. Since 1996, total eight times forest fires recently have been occurred in East-coast of Gangwon province. Forest fire has been occurred with frequency in 2000. The biggest forest fire was that for 17,097ha in Samcheok-si at 2000. As a result of analysis of spatial distribution for forest fire in Samcheok-si at 2000, it is the largest damaged area that approximately 5,882ha occurred on elevation 50~100m and 8,630ha occurred on slope-angles 20~30°.



Elevation (m)	Area (ha)	Slope	Area (ha)	Aspect	Area (ha)
Below 100	3946.5	Below 10	2856.8	N	2144.3
100 ~ 200	5882.0	10 ~ 20	3645.5	NE	2685.0
200 ~ 300	3695.5	20 ~ 30	8630.3	E	2837.3
300 ~ 400	2386.3	Above 30	5627.8	SE	2859.8
400 ~ 500	1747.0			S	1731.8
500 ~ 600	1491.8			SW	2065.0
600 ~ 700	968.0			W	1912.5
800 ~ 900	486.0			NW	1746.5
900~1000	144.5			Flat	2778.3

Elevation (m)	Area (ha)	Slope	Area (ha)	Aspect	Area (ha)
Below 50	113.8	Below 10	471.5	N	221.0
50 ~ 100	525.5	10 ~ 20	507.8	NE	235.5
100 ~ 150	328.3	20 ~ 30	982.8	E	258.0
150 ~ 200	262.8	Above 30	414.3	SE	307.0
200 ~ 250	250.3			S	292.0
250 ~ 300	227.0			SW	239.3
300 ~ 350	247.3			W	187.0
350 ~ 400	225.0			NW	190.5
400 ~ 450	152.0			Flat	446.0

Figure 1. Distribution of forest fire damaged areas in Samcheok-si and Donghae-si

Characteristics of forest type in forest fire damaged areas

Pine forests damaged around 9,500ha were the major damaged forest type. Age class Ⅱ(from 11 to 20 years) has been mostly damaged among the forest type D. Based on the information by the 4th forest type map DB, 90% of the burned area was coverd by trees, i.e., it was a wooded-forest of pine types described above, although very young pine stands are also frequently considered as wooded-forest.

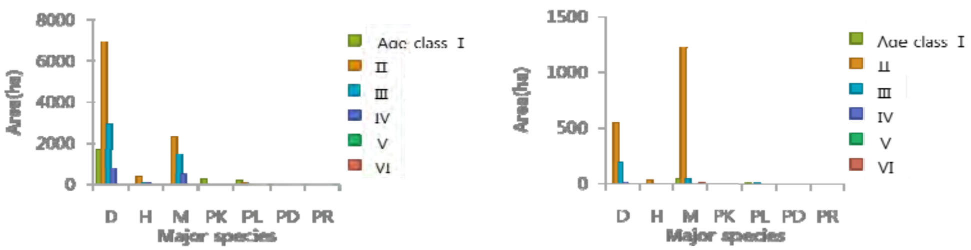


Figure 2. Damaged area by age class in Samcheok-si and Donghae-si

Trends of forest fire in East-coast area

Forest fire damaged areas in East-coast of Gangwon province is highly susceptible to forest fires because of stand structure and topographic and climatic conditions. The forest is currently characterized by thick growth because of inadequate thinning and remaining debris, and its thick layer of fallen leaves catches fire and burns easily. Forest fires also spread rapidly in these mountainous areas (fires spread eight times faster on steep slopes than to level ground).

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The Spatial Change of Forest Fire Occurrence during the Spring Season between 1990s and 2000s

1990년대와 2000년대 봄철 산불발생의 공간적 변화 분석

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Abstract

For efficient forest fire management in Korea, we need to minimize the damage of forest fire and manage them systematically. Therefore, This study aims to analyze the spatial change of forest fire occurrences during the spring season(February to April) between 1990s and 2000s. To analyze the frequencies of forest fire occurrence, we used a comprehensive database from the forest fire inventory from 1991 to 2009 and analyzed the spatial patterns of fire occurrence at the interval of ten days between 1990s and 2000s. As a result of analysis, early April showed the highest frequency of forest fire occurrence both 1990s and 2000s. Compared to the 1990s and 2000s, the regional change of forest fire showed the most frequent fire events around Chungcheong province. Especially extra 27 fires increased in Daejeon city, and the second most frequent fire had more than 10 fires in Jeolla province and Incheon. However, the number of fire frequency decreased by 12 fires at the end of April in Hongcheon county(the province of Gangwon). This is the largest drop over the study period.

요약

본 연구에서는 집중적으로 발생하는 봄철(2～4월) 산불을 효율적이고 체계적으로 관리하기 위하여 19년간(1991～2009년) 발생한 봄철 산불을 1990년대와 2000년대로 나누어 순기별 산불발생빈도 공간패턴을 분석하고 연대별에 따른 순기별 산불발생빈도 변화패턴을 분석하였다. 분석 결과 1990년대와

2000년대에 가장 높은 산불발생빈도를 나타낸 순기가 4월 상순으로 같았지만 이에 대한 지역별 산불발생빈도가 한반도 서쪽 지역인 충청지역을 중심으로 대전에서 27건으로 가장 많이 증가하였고, 호남 및 인천지역에서 10건 이상 증가한 것으로 분석되었다. 그러나 강원 홍천지역에서는 4월 하순에 최대 12건이 감소한 것으로 나타났다.

Introduction

우리나라에서는 1991년부터 2009년까지 연평균 448건의 산불이 발생하였고, 이 중에서 73%에 해당하는 산불이 봄철 건조기인 2월과 4월 사이에 집중적으로 발생하였다(산림청, 2009). 또한 최근 5년간(2001~2005년) 발생한 산불 2,715건 중 봄철 산불은 1,824건으로 전체의 67%를 차지하고 있다(원명수 등, 2006). 따라서 본 연구에서는 집중적으로 발생하는 봄철(2～4월) 산불을 효율적이고 체계적으로 관리하기 위하여 19년간(1991～2009년) 발생한 봄철 산불을 1990년대와 2000년대로 나누어 순기별 산불발생빈도의 공간적인 발생패턴을 분석하고 1990년대와 2000년대의 산불발생빈도 변화를 분석하고자 하였다.

Methodology

먼저 국립산림과학원에서 개발된 산불연구정보시스템을 활용하여 19년간(1991~2009년) 발생한 산불발생위치를 연속지적도의 PNU코드(19자리수)와 매칭하여 산불발생위치 포인트 테이터를 지적의 중심점으로 하여 공간자료화하였다. 구축된 산불발생위치자료는 1990년대와 2000년대로 나누어 봄철 순기별 따른 165개 시·군별 산불발생빈도 데이터를 행정구역별 폴리건과 포인트 정보를 결합한 후 ArcGIS Ver.9.2 프로그램을 이용하여 1km×1km 공간 해상도로 IDW(Inverse Distance Weighting, 보간법)분석을 실시하였다. 1990년대와 2000년대로 나누어 순기에 따른 각각의 산불발생빈도 분석 결과는 다시 1990년대와 2000년대의 지역별·순기별 각 래스터별로 시군의 공간적 빈도변화 차이를 분석하였다.

Results and Discussion

1990년대 대비 2000년대의 봄철을 순기별 산불발생빈도 변화를 분석한 결과, 3월 중순>4월 상순>3월 하순 순으로 2000년대의 산불발생빈도가 증가한 것으로 분석되었다. 2000년대에는 1990년대에 비하여 3월 중순부터 4월 상순까지의 산불발생지역의 공간적 분포가 넓게 나타났다. 1990년대에 비하여 2000년

대의 산불발생빈도 변화가 가장 많이 증가한 지역은 3월 하순과 4월 중순에 대전에서 27건으로 나타났다. 또한 5개 광역시는 산불발생빈도가 전부 증가되는 경향을 나타냈다. 반면에 4월에 집중적으로 발생했던 강원 지역 중 강원 홍천에서 4월 하순에 12건의 산불이 감소하여 가장 큰 감소폭을 보였다. 2000년대는 1990년대에 비하여 2월 초순부터 영남과 강원 영동지역에서 증가하는 패턴을 보이면서 3월 중순부터는 전국적으로 발생빈도 변화량이 커졌다. 3월 하순으로 접어들면서 강원 지역을 제외하고 전 지역에서 증가되었고 4월 초순에는 충청(대전 포함)과 호남(광주 포함)지역을 중심으로 10건 이상 증가하는 산불발생 빈도변화를 나타냈다. 따라서 본 연구 분석 결과, 1990년대와 2000년대에 가장 높은 산불발생빈도를 나타낸 것이 4월 상순으로 같았지만 이에 대한 지역별 산불발생빈도가 한반도 서쪽 지역인 충청지역을 중심으로 호남지역과 인천이 높게 나타나는 경향을 보였다.

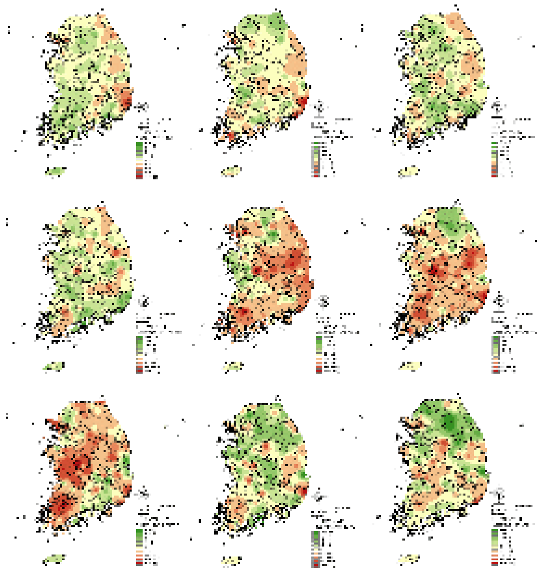

Figure 1. Change of forest fire frequency of ten-days intervals from February to April between 1990s and 2000s.

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Chemical Composition of Precipitation and Wet Deposition in Forest Area, Gangwon.

강원산림지역에서의 강수화학성 특성

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Abstract

To look into the degree of the long distance movement of the air pollution within Mt. Kyebang, Hongcheon one of the clean regions in Korea, major ions, components of collected precipitation, were analyzed by using the ion-chromatography after measuring pH and electrical conductivity. The quality assurance of chemical composition data was checked by considering the ion balance and electrical conductivity. Also, the pH of precipitation showed in the pH5.0~5.5 range, less than the pH5.6 in which the standards of the acid precipitation. On the whole, the more precipitation got, the less ion concentration became: It could showed what it influenced on the fluctuation of the precipitation pH according to fluctuation and neutralization of the according materials. In the meantime, as composition ratios of wet deposition, SO_4^{2-} and nss-SO_4^{2-} of anions, NH_4^+ and nss-Ca^{2+} of cations accounted for high percentage. Especially, as the concentration of SO_4^{2-}, the artificial pollutant, and Ca^{2+}, the soil substance, showed high, Mt. Kyebang, Hongcheon having barely fixed air-pollutants sources was most likely to be influenced by the pollutants moved from long distances.

요약

대기오염은 인구밀집지역 및 산업물질에 의한 인위적오염원과 산불 및 해염입자 등에 의한 자연적 오염원에 의하여 영향을 받는다. 특히 배출오염원이 적은 산림내에서는 자연적 오염원과 인위적 오염원에 의한 장거리 이동에 의하여 대기오염에 영향을 받을 수 있다. 본 연구에서는 강원도 내 비오염지역인 홍천 계방산지역내의 대기오염물질의 유입정도를 알아보고자 이 지역 내의 강수를 채취하여 산도(pH) 및 이온분석을 실시하였다. 분석 자료에 대한 이온수지와 전기전도도(EC) 검토에서 신뢰

성이 확인되었고 홍천 계방산지역 내 강수산도(pH)는 산성우의 기준이 되는 pH5.6이하의 범위인 pH5.0~5.5범위에 집중적으로 나타났다. 대체적으로 강수량이 많을수록 이온농도가 감소하는 경향을 나타내었고 산성원인물질의 증감과 중화물질에 따라 강수산도(pH)의 증감에 영향을 미치는 것을 알 수 있었다. 한편, 강수 중 이온성분의 조성비율을 살펴보면 음이온은 SO_4^{2-}와 nss-SO_4^{2-}, 양이온은 NH_4^+와 nss-Ca^{2+}가 많은 비율을 차지하였다. 특히 대기오염물질 배출원이 거의 없는 홍천 계방산지역에서 SO_4^{2-}와 Ca^{2+}의 농도가 높았던 결과를 통해 이곳의 강수 화학성이 장거리 이동성 물질에 의해 영향을 받고 있음을 추정할 수 있다.

Introduction

Evaluating acidity of precipitation is essential to understand the influence of air pollution on forest ecology. As local and overseas researches on ion-composition by precipitation reported, it is known that the long-distance movement of air polluting elements and yellow dust do affect Korea. For this, chemical researches of precipitation composition are under study based on urban area and coastal areas including the Westsea, yet studies on long-distance movement for mountainous regions with rather lower pollution level have rarely performed. Thus, this research has targeted the less polluted region of Mt. Kyebangin Hongcheon, Gangwon-do to measure the influx of pollutants caused by the long distance movement with precipitation pH analysis as well as ion-composition and the balance.

Methodology

The collected samples were cold-stored under 4℃, and then filtered through 0.45㎛membrane filter to measure EC and pH per each. The concentration of anion(NO_3^-,Cl^-, SO_4^{2-} and cation(NH_4^+,Ca^{2+},Mg^{2+},K^+,Na^+) were analyzed utilizing ion-chromatography. The pH average is calculated converting the pH value into hydrogen ion concentration, precipitation being weighted average, and reconverting into pH; then the reliability verification of the precipitation analysis data was carried to minimize the margin of error. There liability verification for ion- exchange resin and EC (electrity conductivity) balance was performed by checking of the monthly average value of total samples.

Results and Discussion

The Reliability Verification on Precipitation Analysis Data

The total linear slope between total anion concentration and total cation concentration was 1.1044, close to1, and R^2 marked 0.9147($P<0.001$) to prove there liability of analysis results, while the balance between cation and anion showed relatively fine. The total of cation marked relatively higher than one of anion, which appears to be influenced by other ions with out anion analyzed element, including HCO_3^- and organic acid such as formic acid and acetic acid. The calculated value of electrical conductivity showed higher than the measured value of electrical conductivity; yet judging from the total slope marked 0.4412 and R^2 was 0.8938($P<0.001$), the significance level is high and the balance between measured electrical conductivity and calculated electrical conductivity shows comparably fine.

The pH Distribution of Precipitation

The pH appearance-frequency of measured precipitation shows that over 80% of precipitation on the region of Mt.Kyebang, Hongcheon located between the range of pH 5.0~5.5.

The Relation between pH and Precipitation

Precipitation is measured between the range of 2.0~115.6mm with average 51.88±54.82mm. It shows pH widely spread at precipitation below 50mm. This appears the high influence of fine particle in the air and polluted gas materials.

The Ion-Composition by Precipitation

The ion-composition ratio of monthly precipitation in 2008 shows anion in the order of SO_4^{2-} > nss- SO_4^{2-} > NO_3 > Cl^-, while cation in the order of NH_4^+ > nss- Ca^{2+} > Ca^{2+} > Na^+ > Mg^{2+}, K^+, The major base element NH_4^+ ion is followed by Ca^{2+} high as 25%. Among the precipitation elements, Ca^{2+} is caused from ocean, but also from artificial pollutant such as pavedroad, as well as natural pollutant of soil evaporated from surface to the air by wind or yellow dust caused by the long- distance movement from desert area. Considering that there is a few artificial pollutant in Hongcheon area with comparatively less traffic and less pollutant rate nearby, the major influence is presumed from yellow dust moved long distance. Also with the fact that SO_4^{2-} takes 33% of anion, and nss SO_4^{2-}

takes 31%. We expected that the major cause comes from fire smoke, artificial pollution by SO_4^{2-}, yet Hongcheon of the clean area is affected by long distance movement of air pollution substances occurred out side of the region.

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Trends of Timber Products in East Coast Forest Fire Area after 2000 in Korea

2000년 이후 동해안 산불 지역의 목재생산 추이

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Abstract

The east coast forest was damaged by forest fire in April 2000 in Gangwon-do and the area burnt was about 23,794ha. This was about 1.7% of forest area in Gangwon-do. The damaged timber was 1,539 thousand ㎥, was 97% of domestic timber production (1,592 thousand ㎥ in 2000). After the forest fire on the east coast in 2000, timber production in Gangwon-do decreased by 2003. After that, timber production is rising gradually.

After 2006, with the rise in domestic timber production, timber has been produced more than 300 thousand per year in Gangwon-do. By regional groups, timber production in Gangneung and Samcheok was double in 2000 compared with other years then the production has increased steadily. In 2001, timber production in Donghae was 10 thousand m^3 which was five times more than in 2000, however, after that became similar to production in the average year. It was probably caused by supplying wood which can be used as timber since damaged tree had been removed.

요약

2000년 4월에 강원도 동해안 지역의 산불로 약 23,794ha의 산림이 피해를 받았다. 이는 강원도 산림면적의 약 1.7%에 해당되며, 당시 피해 축적은 1,539천㎥으로, 2000년 국내재 생산량인 1,592천㎥의 86%에 해당된다. 2000년 동해안 산불 이후 강원도의 목재생산은 2003년까지 감소를 보이다가 이후 점차 증가를 보이고 있는 것으로 나타났다.

2006년 이후 우리나라의 국내재 생산량이 증가되면서 강원도에서는 매년 300천㎥ 이상을 생산하는 것으로 나타났다. 지역별로 보면, 강릉과 삼척지

역의 경우 2000년에는 예년의 2배에 달하는 생산을 보였으며 이 이후에는 꾸준히 증가하는 추세를 보이고 있다. 동해시에서는 2001년에 2000년의 5배에 달하는 약 10천㎥을 생산하기도 하였으나 이후 예년 수준으로 나타났다. 이러한 현상은 동해안 산불로 피해목 제거를 하면서 용재로서 사용이 가능한 목재를 공급하여 나타난 측면도 있는 것으로 추정된다.

서론(Introduction)

우리나라는 정부수립 이후 1996년에 최대규모인 강원도 고성산불(3,762 ha) 등 5,368㏊에 달하는 산불피해 발생하였으며, 2000년 4월에는 고성, 동해, 강릉, 삼척 울진산불이 동해안지역을 따라 거의 동시다발적으로 발생하여 건국이래 최대의 23,794ha 초대형 산불피해가 나타났다.

우리나라의 목재 생산량은 2009년 현재 3,176천㎥로, 2000년도 동해안 산불로 피해를 받은 산림피해 재적량인 1,539천㎥의 약 2배에 해당된다. 강원도에서는 동해안 산불이 발생한 2000년을 중심으로 2003년까지 감소를 보이다가 이후 증가를 나타내고 있다. 이 연구는 2000년 동해안 산불피해가 발생한 지역을 중심으로 행정구역별로 목재생산과 관련된 통계자료를 이용하여 1995년부터 2009년까지 목재생산의 변화를 분석하였다.

재료 및 방법(Methodology)

동해안 산불지역의 목재 생산의 추이는 임업통계연보와 임산물생산통계 및 해당 시군 통계에서 자료를 확보할 수 있는 생산량 및 생산액의 자료를 이용하여 분석하였다. 시계열 자료는 1995년부터 2009년까지의 data를 이용하였으며, 이중 임상별 자료를 확보할 수 있는 경우에는 이 자료를 이용하여 생산액과 생산액의 추이도 함께 분석하였다.

한편, 산림청의 통계자료와 지방정부의 통계자료와 일치하지 않는 경우에는 산림청의 통계자료를 이용하였으며, 일부 통계 data의 경우에는 해당 지방정부의 통계를 이용하여 분석하였다.

결과 및 고찰(Results and Discussion)

2000년 동해안지역의 산불피해 면적은 총 23,794㏊로 영급별로 살펴보면,

Ⅰ영급이 3,348ha, Ⅱ영급이 3,280ha, Ⅲ영급이 7782ha, Ⅳ영급이 8446ha, Ⅴ영급이 848ha이다. 시군별로 보면, 고성군이 2,696ha, 강릉시가 1,447ha, 동해시가 2,224ha, 삼척시가 17,097ha, 울진군이 310ha로 나타났다. 고성군은 대부분 Ⅰ영급이 피해를 입었으며, 강릉시는 Ⅳ영급, 동해시도 Ⅳ영급에서 피해를 많이 받은 것으로 나타났으며, 삼척시는 Ⅲ~Ⅳ영급에서 피해가 많은 것으로 나타났다. 울진군은 Ⅱ~Ⅲ영급에서 피해면적이 많은 것으로 나타났다.

표 1. 시군별 영급별 산불피해 면적

단위 : ha

구분	계	Ⅰ영급	Ⅱ영급	Ⅲ영급	Ⅳ영급	Ⅴ영급
계	23,794	3,438	3,280	7,782	8,446	848
고성	2,696	1,828	6	820	42	0
강릉	1,447	216	157	529	508	37
동해	2,244	228	56	497	1,444	19
삼척	17,097	1,161	2,942	5,781	6,421	792
울진	310	5	119	155	31	0

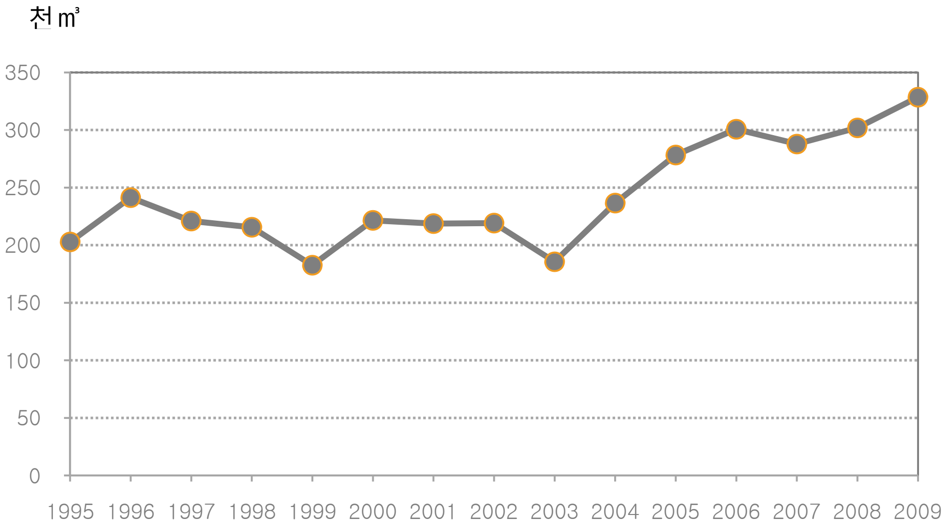
한편 2000년 동해안지역의 산불피해 축적은 총 1,539천㎥로 영급별로 살펴보면, Ⅱ영급이 123 천㎥, Ⅲ영급이 461천㎥, Ⅳ영급이 853, Ⅴ영급이 101 천㎥이다. 시군별로 보면, 고성군이 52 천㎥, 강릉시가 134 천㎥, 동해시가 163 천㎥, 삼척시가 1,171 천㎥, 울진군이 18 천㎥로 나타났다. 산불피해 축적중 용재로서의 가치가 있다고 판단되는 Ⅲ영급 이상이 약 92%에 해당된다

표 2. 시군별 영급별 산불피해 축적

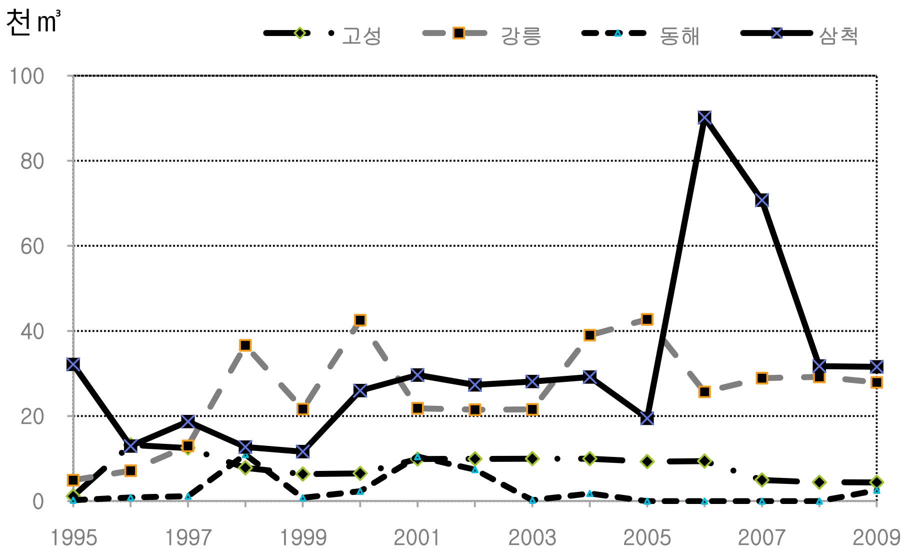
단위 : ㎥

구분	계	Ⅰ영급	Ⅱ영급	Ⅲ영급	Ⅳ영급	Ⅴ영급
계	1,539,108	0	123,308	461,140	853,443	101,217
고성	52,059	0	174	47,949	3,936	0
강릉	134,478	0	9,113	45,856	76,237	3,272
동해	163,790	0	1,940	27,248	132,302	2,300
삼척	1,170,635	0	107,321	329,522	638,147	95,645
울진	18,146	0	4,760	10,565	2,821	0

2000년 동해안 산불이 발생한 강원도의 목재생산량의 추이를 보면 그림 1과 같이 산불이 발생한 2000년부터 3년간 감소하는 경향을 보이다가 2003년 이후 목재생산은 증가하는 모습을 나타내고 있다.



산불피해를 입은 지역의 목재생산은 그림 2에서 보는 바와 같이 삼척시의 경우 산불발생 이후 4년간은 정체현상을 보였으나 이후 약간 증가하는 추이를 보이고 있다. 강릉시의 경우 산불발생 이후 2003년까지는 절반 수준으로 감소를 보이다가 이후 약간 증가하는 추이를 보이고 있으며, 고성군의 경우 산불 발생에도 불구하고 2006년까지는 증가를 보이다가 이후 감소하는 경향을 나타내고 있다. 동해시의 경우 산불발생 이후 증가하였다가 2003년 이후부터는 정체 현상을 보이고 있다.



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Monitoring of Vegetation Recovery in the East Coastal Forest Bunt Area of Korea using Multi-temporal Landsat Images

다시기 Landsat 영상을 이용한 동해안 산불지역의 식생 회복 모니터링

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Abstract

Using multi-temporal Landsat TM data, NDVI and MSI changes over times were analyzed according to forest type and damage class in order to examine the vegetation recovery after forest fire. NDVI values were rapidly decreased and MSI values were increased after containment of the fire and gradually increased over times. NDVI and MSI curves of coniferous forest - especially red pine forest - yielded the lowest and highest values respectively. In 2007, NDVI and MSI recovery rate was within about 98% and 93% respectively. It was shown that recovery of MSI was small in severely damaged area. Topographical characteristics of short-term recovery area was different from that of long-term recovery area.

요약

산불 이후의 식생 회복을 조사하기 하여 다시기 Landsat TM 위성영상을 이용하여 NDVI와 MSI의 변화를 분석하였다. 산불 발생에 이후, NDVI 값은 빠르게 감소하고 MSI는 증가하였으며 그 후 점차 값이 회복되었다. 2007년 현재, 산불미피해지와 비교했을 때 NDVI를 통해 추정한 산불피해지의 식생활력도는 전체적으로 약 98% 회복이 되었으며, MSI를 통해 추정한 수분스트레스는 약 93% 회복되었다. 임상별로는 회복력의 차이가 뚜렷하게 나타나지 않았으나,

수분스트레스는 산불피해강도가 클수록 회복률이 작은 것으로 나타났다. 단기간에 빠른 식생회복을 보인 산불피해지는 장기간에 큰 식생회복을 보인 지역과 비교 했을 때, 서로 다른 지형 특성을 보였다.

Introduction

The objective of this study was to detect vegetation recovery over times after forest fire occurred in Samcheok city in April 2000, using multi-temporal Landsat image data obtained in 1989, 2000, 2001 and 2007. Also, topographic factors that affect vegetation recovery are analyzed according to recovery time. In order to examine the vegetation changes over times, NDVI and MSI values were derived from time series image data sets.

Methodology

Multi-temporal Thematic Mapper(TM) image data obtained from Landsat-5 were used for this study. The forest fire over the study area was broke out in April. Four analysis images created in 1998, 2000, 2001 and 2007 were analyzed in this study. All images were geometrically referenced to Korean TM(Eastern) projection. Bands 1 through 5 and 7 were converted to at-satellite planetary reflectance.


(a) May 20, 1998 (b) May 25, 2000 (c) May 28, 2001 (d) August 17, 2007

Figure 1. Satellite image data used for change detection

NDVI(Normalized Difference Vegetation Index) and MSI(Moisture Stress Index) changes over times were analyzed according to forest type and damage class in order to examine the vegetation recovery after forest fire. NDVI is a typical index to assess the vegetation vitalirty(Eq. 2). MSI is used to assess water content within vegetation canopy(Eq. 2). Also this index has been shown to be very effective for mapping forest damage(Vogelmann et al., 2009). Relative NDVI and relative MSI were used to analyze relative recovery rate of damaged area compared to undamaged area.

$$NDVI = \frac{NIR(Band4) - Red(Band3)}{NIR(Band4) + Red(Band3)} \qquad \text{Eq.1}$$

$$MSI = \frac{MidIR(Band5)}{NIR(Band4)} \qquad \text{Eq.2}$$

$$Relative\ index = \frac{Index_{damaged}}{Index_{undamaged}} \times 100 \qquad \text{Eq.3}$$

Results and Discussion

- Interpretation of Forest Damage by Image Differencing

The differences of vegetation change were distinctively appeared in both band3 and band4 after containment of the fire. NDVI value was rapidly decreased and MSI value was increased after fire. This changes were gradually recovered since that time (Figure 2).

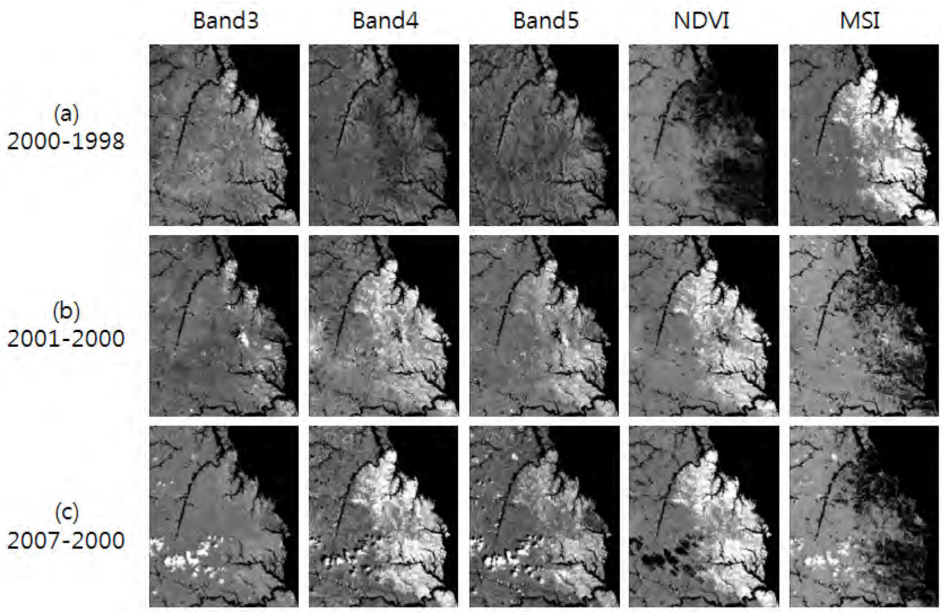

Figure 2. Image differencing between pre-fire and post-fire image

- Vegetation Recovery of Burnt Forest

NDVI and MSI curves of coniferous forest - especially red pine forest - yielded the lowest and highest values respectively. In fact, most of the red pine forest in study area were prone to forest fire and severely damaged(Figure 3). In 2007, NDVI and MSI recovery rate according to forest type was within 97~99% and 92~95% respectively. NDVI and MSI recovery rate according to damage class was within 98~99 % and 90~97% respectively. It was shown that recovery of MSI was small in severely damaged area.

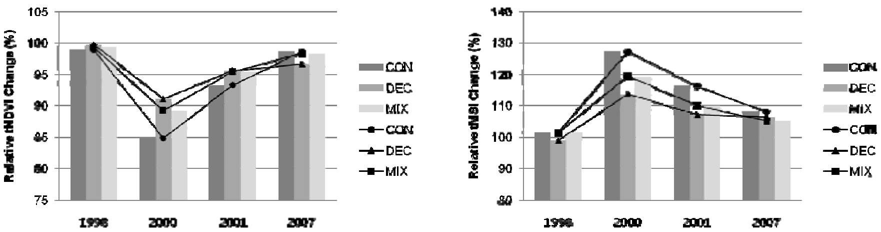

Figure 3. Relative NDVI and relative MSI change according to forest types

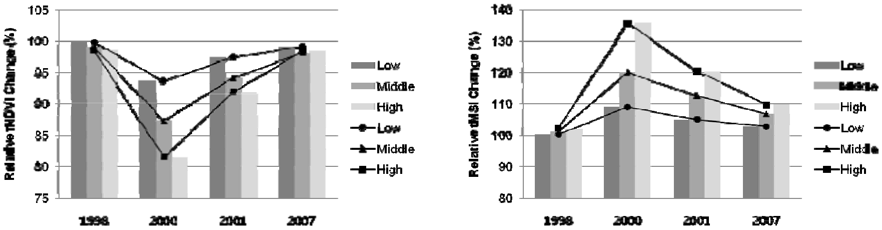

Figure 4. Relative NDVI and relative MSI change according to damage class

- Short-term and Long-term Recovery

Short-term and Long-term recovery area of severely damaged area were selected and topographical characteristics of these areas were examined. Short-term recovery was operated in low elevation area, low slope area compared to total severely damaged area. And long-term recovery was operated in eastern and southern slope. Main impact factor of short-term recovery was elevation and slope related to connectivity and impact factor of long-term recovery was aspect related to solar radiation.

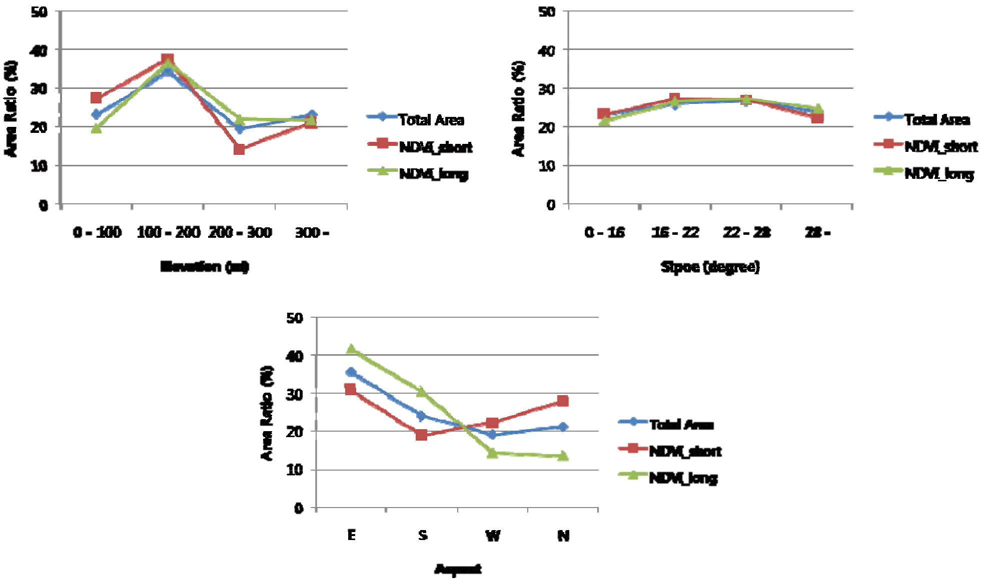

Figure 5. Topographical characteristics of short/long-term recovery area

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Mapping and Evaluation of Forest Carbon Stock derived from the National Forest Inventory Data and Landsat Imagery

국가산림자원조사와 위성영상 자료를 이용한 산림 탄소축적량 주제도 제작 및 평가

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Abstract

As carbon sink, forests play a critical role. This study was implemented to produce a forest carbon stock map at the county level and to asses the produced map. Field plot data from the national forest inventory were used as training (surveyed in 2006-2008) and as an independent dataset (surveyed in 2009) data. In order to produce the thematic map, the *k*-nearest neighbor (*k*NN) technique was applied by combining field data and Landsat TM. Forest carbon stock maps were produced with *k*=5 and their accuracy were evaluated with the independent dataset. It was resulted that the relative root mean square error and mean deviation for overall data-set were estimated to be 38.5% and -1.8 Cton/ha, respectively.

요약

기후변화와 관련하여 탄소흡수원으로써 산림의 역할은 점차 증가되고 있다. 본 연구는 산림 탄소축적량의 공간적 분포를 나타낼 수 있는 산림탄소축적량을 제작하고 검증하기 위하여 수행하였다. 국가산림자원조사에서 수집된 야외 표본점 자료를 훈련(2006-2008) 및 검증자료(2009)를 이용하였으며, Landsat 영상과 통합하여 k-nearest neighbor 기법에 의해 시군 단위의 산림 탄소축적량 주제도를 생산하였다(k=5). 2009년에 수집된 78개 표본점 자료를 이

용하여 주제도를 검증한 결과 전체 상대추정오차율은 38.5%, 평균편의는 -1.8 Cton/ha로 나타났다.

Introduction

In the context of climate change, the role of forests as carbon sink is expanded. A national forest inventory has been implemented to assess forest resources in Korea. To efficiently manage forest carbon stock, it is a necessary of its thematic map. Forest carbon map can be produced by combining field plot data and ancillary information such as satellite data or aerial photo which covers including non-observed areas across an area of interest. The objective of this study was to produce a forest carbon stock map and to evaluate a produced map.

Methodology

Material

In this study, field data from the 5th National Forest Inventory (NFI) were used for mapping and verification of forest carbon stock. The NFI-field plots consisting of 4 sub-plots were systematically distributed over the entire country with a grid size of 4km. Table 1 shows the information of field plots and satellite image used in this study. Field plots surveyed in 2006-2008 years were employed to predict forest carbon stock at unmeasured plots as training dataset and those in surveyed in 2009 year were used to evaluate a produced forest carbon stock map. Forest carbon stock per plot was computed with BCF/BEF and CCF by forest type. Landsat TM-5 that has been popularly used forest resources assessment over a large area was acquired at May and June 2009. The image was geometrically corrected with a digital map.

Table 6. Number of field plots and satellite imagery for mapping forest carbon stock for each study site

Classification	Landsat TM-5		
	115-34		115-35
Study site	Yangpyong	Wonju	Seongju
Acquisition date	25. May 2009		26. June 2009
Num. of training plots	2,804	2,804	2,784
Num. of plots for evaluating	29	31	18

k-Nearest Neighbor(*k*-NN) technique

The *k*-NN technique is mostly used to produce thematic maps by combining field plot data and satellite data. Table 3 shows the equations and estimators used in the *k*-NN method.

Table 7. Equations and estimator used in the k-NN technique.

Euclidean distance	Distance-weighting	Carbon stock estimator
$d_{t,r} = \left[\sum_{i=1}^{m}(x_{i,r} - x_{i,t})^2\right]^{\frac{1}{2}}$	$w_{t,r} = \dfrac{\left(\frac{1}{d_{t,r}}\right)}{\sum\left(\frac{1}{d_{t,r}}\right)}$	$\hat{c}_t = \sum_{r=1}^{k} w_{t,r} \times c_r$

$x_{i,t}$: spectral values at target plot i , $x_{i,r}$: spectral value at reference plot i, m : number of bands, and

$d_{t,r}$: distance between target and reference plots on spectral feature

Mapping and Evaluation

In order to assess the *k*-NN estimates for different number of *k*, a cross validation was used. RMSE, relative RMSE, and mean deviation were computed as following equations in Table 3. An optimal value of *k* for each county was selected. For evaluating *k*-NN estimates, independent field data (n=78) surveyed in 2009 were used.

Table 8. Assessment Statistics used in this study.

RMSE	RMSEr	Mean deviation
$RMSE = \sqrt{\dfrac{\sum_{i=1}^{n}(c_i - \hat{c}_i)^2}{n}}$	$RMSEr = \dfrac{RMSE}{\bar{\hat{c}}} \times 100$	$MD = \dfrac{\sum_{i=1}^{n}(c_i - \hat{c}_i)}{n}$

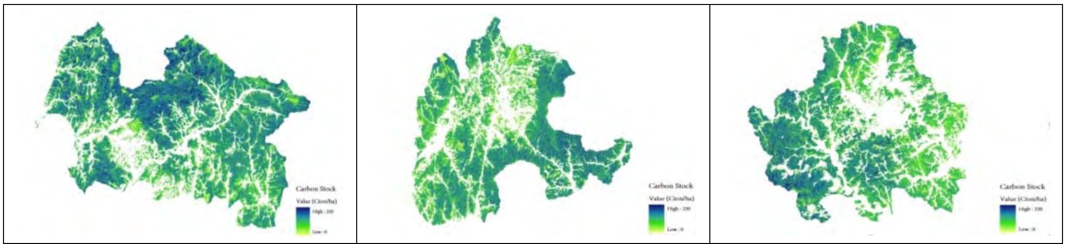
where c_i and $\hat{c}_i$ are observed value and estimated value at the plot *i*,

$\bar{\hat{c}}$ is a mean of estimates, and *n* is number of field plots used.

Results and Discussion

Forest carbon stock map

From a leave-one-out assessment, an optimal value of *k* (*k*=5) was selected and carbon stock maps were produced. With digital forest maps, non-forest areas were eliminated (Figure 1).



(a) Yangpyeong county	(b) Wonju city	(c) Seongju county

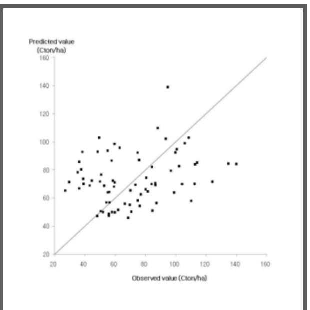
Figure 1. Forest carbon stock map for each study site (*k*=5)

Evaluation of forest carbon stock map

A number of field plots used for evaluating per county were a few from 18 to 31. In the case of Seongju, the relative RMSE and MD were the largest (41.8% and 10.4 Cton/ha, respectively) as shown in table 4. As a result, those of overall dataset were 38.4% and -1.8 Cton/ha.

Table 9. Accuracy assessment with field data surveyed in 2009 (n=78)

Classification	No. of field plots	RMSE (Cton/ha)	Relative RMSE(%)	MD (Cton/ha)
Yangpyeong	29	30.1	38.6	-6.5
Wonju	31	25.6	35.9	-4.2
Seongju	18	26.8	41.8	10.4
overall	78	27.7	38.4	-1.8



Comparision of Small Aera Estimation Techniqes for Providing Forest Growing Stock Volume from NFI5 Field Data

국가산림자원조사자료를 활용한 소면적 산림통계 산출기법 비교

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Abstract

The 5th National Forest Inventory (NFI5) was implemented in 2006~2010 for providing forest resources statistics. Forest information at county level is impoitant to forest policy making. Since a number of field plots in a county are insufficient, small area estimation (SAE) has been mostly applied. In this study, three small area estimation methods; direct estimation (DE), synthetic estimation using field data within neighboring a county (SNE) and within a boundry based on distance from a county of interest (GE), were compared to evaluate forest statistic at county level. As it turnd out GE could be provide more reliable information.

요약

우리나라에서는 보다 과학적인 전국단위 산림기본통계 생산과 임목자원 및 산림환경생태자원 정보의 수집을 목적으로 2006년부터 2010년 까지 제5차 국가산림자원조사를 수행한바 있다. 본 연구에서는 원활한 정책수립과 통계적 수요가 많은 시군구의 산림통계 산출을 위하여 보조정보의 획득이 어려운 우리나라의 실정에 맞추어 소면적 통계추정방법인 합성추정법의 적용가능성을 모색하고자 한다. 이에 경기도지역, 31개 시군구의 표본점자료를 바탕으로 직

접추정법과 합성추정법(이웃시군기반 및 거리버퍼기반)을 비교함으로서 보다 효율적인 합성추정의 적용방안을 모색하였으며, ha당 임목축적과 상대추정오차를 비교한결과 거리버퍼기반 합성추정법이 다른 방법보다 정확한 추정이 가능한 것으로 나타났다.

Introduction

In Korea, the 5th National Forest Inventory (NFI5) was implemented in 2006~2010 for evaluating forest resources statistics. Although the NFI5 was designed to provide forest resources statistics at the national level, forest statistics at county level that is important information for NFI users and decision-making should be derived from NFI data. SAE has been populary applied to provide information for sub-population that did not consider sampling design. Synethic estimation is a method of SAE and used ancillary data from neighboring sub-population that has homogenous properties to a sup-population of interest.

Methodology

In this study, growing stock volumes (V/ha) per plot level, were calculated by NFI5 permenat sampled plot (NFI5 PSP) dataset in Geonggi-do that was collected during 2006~2010. NFI5 PSP design is consisting 4 sub-plots as shown in fig 1.

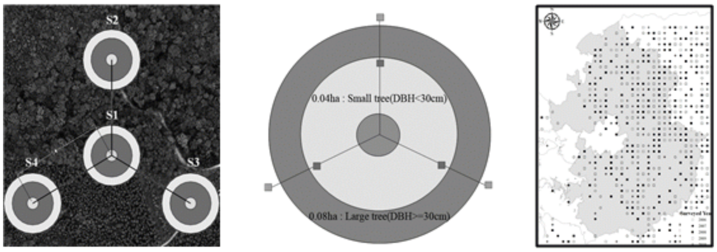

Figure 1. NFI5 PSP design

Three estimation methods were applied; direct estimation (DE), synthetic estimation using field data in neighboring counties (SNE) and geo-spatial estimation (GE). Calibration approaches wewe used for SNE and GE, respectively, as shown in fig 2.

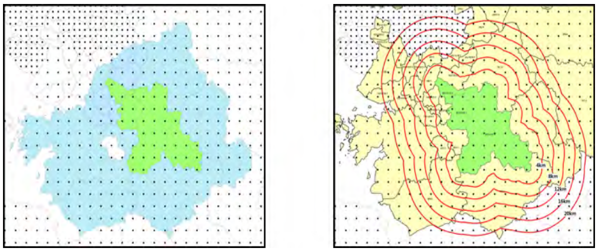

Figure 2. Calibration methods using GIS in case of Yongin (left: SNE, right: GE)

Number of NFI5 PSP (NP) by estimation methods is Table 1 that is main dataset to estimate V/ha and relative standard error (RE). Reasonable distance of GE was selected to closed RE 10% for each county.

Table 1. NP at county level for each estimation method in Geonggi-do

County	NP						
	DE	SNE	GE				
			1km	2km	…		
Gapyung	177	1,186	219	246	…	912	961
Goyang	15	35	30	51	…	301	315
Kwacheon	1	136	15	19	…	235	258
Kwangmyung		131	8	15	…	172	182
Kwangju	69	417	80	98		497	543
Guri		186	4	11	…	325	350
Gunpo	3	23	6	8	…	155	166
Kimpo	4	250	4	8	…	233	246
Namyangju	65	687	80	84	…	656	677
Dongducheon	9	212	9	16	…	327	350
Bucheon	4	205	4	4	…	153	158
Sungnam	13	273	21	36	…	352	379
Suwon	7	121	10	21	…	234	246
Siheung	9	103	13	13	…	162	176
Ansan	8	78	11	16	…	182	195
Ansung	68	341	74	86	…	416	438

County	NP						
	DE	SNE	GE				
			1km	2km	…	23km	24km
Anyang	8	145	19	26	…	208	219
Yangju	35	268	49	63	…	377	391
Yangpyung	138	1,148	161	204	…	861	892
Yeoju	33	483	57	68	…	633	656
Yeoncheon	53	316	66	77	…	307	323
Osan		46			…	159	164
Yongin	65	286	94	108	…	438	461
Uiwang	4	109	4	10	…	215	229
Uijungbu	3	328	15	29	…	326	350
Icheon	23	312	36	44	…	502	543
Paju	43	150	58	65	…	337	361
Pyungtaek	9	292	9	9	…	284	318
Pocheon	115	517	141	167	…	722	737
Hanam	11	268	11	21	…	421	443
Hwasung	37	126	40	41	…	300	320

Results and Discussion

RE variation by estimation method and GE with increasing distance is fig 3. As it results, RE is dcreasing during buffer distance increasing but, it is a slight difference.

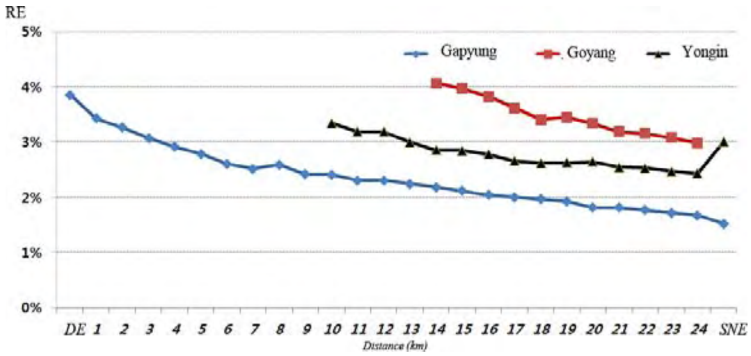

Figure 3. RE variation by methods and GE with increasing distance distance

Some county that was not inventoried or designed need more distance for estimate reasonable RE for example Osan, Kwangmyung. But Gapyung and Yangpyung has reasonable statistics using DE.

Table 2. Comparison of estimation results for each small area estimation method

County	DE			SNE			GE			
	NP	V/ha	RE	NP	V/ha	RE	RD	NP	V/ha	RE
Gapyung	177	128.3	3.8%	1186	143.4	1.5%	0	177	128.3	3.8%
Goyang	15	128.3		35	121.6		13	104	117.4	5.3%
Kwacheon	1	127.1		136	117.6		24	181	130.8	3.7%
Kwangmyung		144.1		131	111.5		24	118	114.5	4.7%
Kwangju	69	159.4		417	141.3	2.4%	6	164	144.1	3.8%
Guri				186	123.3		17	145	138.8	4.5%
Gunpo	3	149.7		23	107.6		24	128	123.5	4.8%
Kimpo	4	101.8		250	117.1	2.7%	22	125	112.5	4.5%
Namyangju	64	130.9		687	134.9	1.9%	3	104	134.6	5.8%
Dongducheon	9	108.7		212	121.4		15	164	125.7	4.9%
Bucheon	4	119.9		205	114.5		24	92	110.5	4.9%
Sungnam	13	160.8		273	134.0	2.7%	14	125	140.8	4.1%
Suwon	7	164.5		121	128.3		17	128	126.2	5.5%
Siheung	9	88.6		103	113.9		24	116	122.5	5.2%
Ansan	8	136.5		78	114.7		23	151	117.3	4.9%
Ansung	68	132.2		341	115.0	3.1%	10	177	121.8	4.1%
Anyang	8	62.4		145	113.3		24	151	122.8	4.2%
Yangju	35	121.6		268	110.1	3.1%	8	143	125.1	5.2%
Yangpyung	136	145.1	4.5%	1148	143.0	1.5%	0	136	145.1	4.5%
Yeoju	33	138.4		483	129.6	2.5%	9	188	129.9	3.8%
Yeoncheon	53	85.0		316	118.6	3.3%	16	206	112.2	4.0%
Osan	0			46	101.5		24	164	124.1	4.6%
Yongin	65	130.8		286	136.8	3.0%	10	210	135.8	3.4%
Uiwang	4	108.8		109	131.8		22	158	130.1	4.0%
Uijungbu	3	57.4		328	127.4	3.0%	14	155	123.4	5.1%
Icheon	23	114.2		312	129.5	3.0%	6	86	129.3	5.3%
Paju	43	112.8		150	106.2		13	152	110.4	4.5%
Pyungtaek	9	36.6		292	116.8	3.6%	21	251	113.8	3.9%
Pocheon	11	139.2		517	123.6	2.5%	1	145	136.2	4.7%
Hanam	115	143.0		268	134.4	2.7%	10	89	138.8	4.9%
Hwasung	37	117.3		126	122.3		20	254	119.9	3.8%

The GE is a more useful method for small area estimation. However, to provide more reasonable forest statistic, it should be needed to integrate various forest inventory data such as urban forest and forest management inventory data.

Analysis on Land-use and Land-cover Change using Medoum Resolution Satellite Image

중해상도 위성영상을 이용한 토지이용 및 토지피복변화 분석

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Abstract

LULCC (Land Use and Land Cover Change) is one of the most important driving forces of disturbances on the Earth's surface. This study discusses the detection of land cover changes in Kangwon Province, Korea, using multitemporal Landsat TM and ancillary data. We compared the performance of Normalized Burn Ratio (NBR) and Normalized Difference Water Index (NDWI) from multisensor data in the image differencing method for detecting the disturbances between 1999 and 2000. We performed geometric and radiometric corrections for the multitemporal Landsat TM data satellite data. The ancillary data, built into GIS database, consists of spatial forest management data, administrative boundary, forest type and road networks. Furthermore, the ARD and burned area masks were acquired from interpretation of aerial-photos and ground-truthing. The accuracy of the detect rate in land cover change area was better in the order of NBR and NDWI. As the best detection method, the NBR differencing was successful in capturing the disturbances between with an accuracy of 89%. The spatial distribution of disturbances was also analyzed.

요약

LULCC(Land Use and Land Cover Change)는 지구표면 교란의 중요한 영향력 중 하나이다. 본 연구는 Landsat TM영상과 보조자료를 이용하여 강원도지역의 토지피복변화지 분석을 실시하였다. 정규탄화지수(NBR)와 정규수분지수(NDWI)를 이용하여 1999년과 2000년 사이의 변화지역을 검출하여 비교하였으

며, Landsat TM영상의 기하보정, 방사보정을 실시하였다. 보조자료는 GIS database로 구축된 산림경영자료, 행정경계, 임상도, 임도망도를 사용하였으며 또한, 현장조사와 항공사진으로 구축된 ARD와 산불자료를 이용하였다. NBR과 NDWI지수를 사용하여 변환된 영상의 토지피복변화지 분석결과 NBR의 일치율이 약 89%로 가장 높게 나타났다.

Introduction

This study examined the possibility of locating the areas where land-use and land-cover are changed using the vegetation indices (NBR, NDWI) drawn from the Landstat TM images of two different timings.

Methodology

ArcGIS 9.3 and ENVI were used for the data analysis of Landstat TM satellite image data. For the statistical analysis of areas with changed land-cover, Excel 2007 and SPSS were used.

A preparation work and standardization work on the Landstat TM satellite image data of two different timings were done. A coordinate correction was done so that the object-site administrative boundary and forest fire damage area boundary would be overlapped. Areas without change in trees, forest and buildings were identified from the two images. Total 15 locations without change were arbitrarily selected (pixel value 5 for each) and image correction was done on those (Figure 2). Regarding the extraction indices selection for the areas with land-cover change, the indices used in the previous research literature on the land-cover change area extraction using satellite image were used first. Then the indices used in the land-use change were chosen (Table 1). The images of two timings were reconciled and the values of changed locations were extracted as land-cover change areas. Then the extracted areas in the land-cover change areas were compared with GIS information and analyzed using average and standard deviation. As last, a Kappa analysis was done to assess the accuracy.

Results and Discussion

A consistency analysis was done on the satellite image and land-cover changed areas using the NBR and NDWI indices converted from Landstat TM satellite image data of two different timings.

Images were converted to NBR and NDWI and grouped for year 2000 and

1999. The changed areas were extracted. Areas that have values lower than the value that is subtracted of standard deviation from average at the interval of 0.5 times were chosen as the changed areas. The consistency is the percentage of extracted pixels on the forest fire damaged area. In the section between μ-1*δ and μ-1.5*δ, NBR was 89%, the highest, and NDWI was 76%. As the section was enlarged, the extracted change areas decreased and the consistency also had decreasing trend. Among the indices, the consistency decrease of NDWI was bigger than that of NBR.

The Khat analysis on the Landsat image was done. In the section of μ-2.5*δ or lower, the consistency was the highest with NBR 65% and NDWI 47%. A filtering was done at the location where the standard deviation with highest consistency of NBR was 2.5 times. Khat indices all decreased. On the other hand, a filtering at the location where the standard deviation is 1 gave the result that both NBR and NDWI increased close to 50%. Therefore, it is believed that NBR index is effective in the extraction of areas that will change from current forest area to non-forest area in the future.

Table1. Detection index

Items	Band used	Formula	Remark
NBR	Band 4, 7	$\frac{\text{Band4} - \text{Band7}}{\text{Band4} + \text{Band7}}$	Grading of forest fire damage, preparation of forest fire damage map
NDWI	Band 4, 5	$\frac{\text{Band4} - \text{Band5}}{\text{Band4} + \text{Band5}}$	Change in plants growth, change in water stress, locating the wet areas

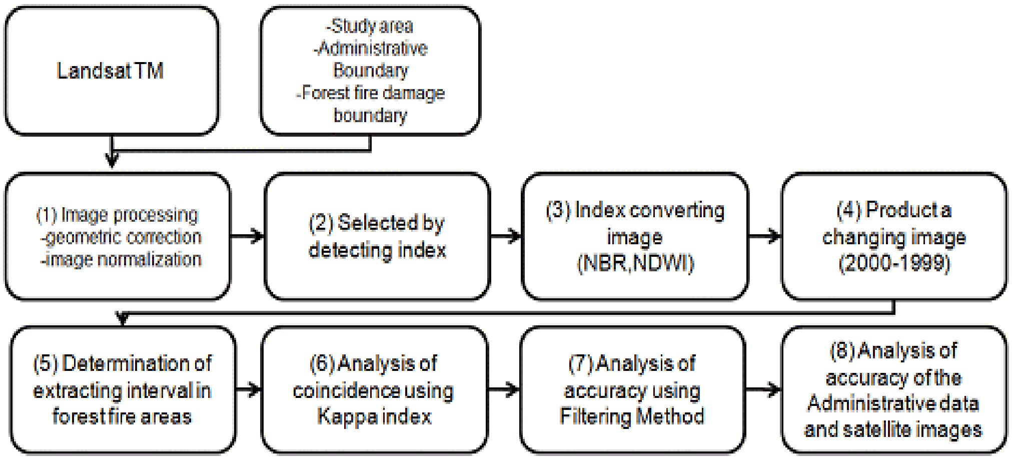

Figure 1. Study method

Forest Cover Change Detection for Mt. Bogdkhan and Tuul River Basin in Mongolia

몽골 복단산과 튤강 지역의 산림 면적 변화

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Abstract

According to the Mongolian Ministry of Nature and Environment, the total forest area in Mongolia has decreased by 1.2 million ha during the last twenty years (about 60,000 ha per year). UNEP report on land cover assessment for Mongolia states the major cause of forest loss and degradation in Mongolia is forest fire. Even though low precipitation in Mongolia creates high fire hazard, about 90 percent of forest fires are caused by human activities. The results of satellite image classification and field surveys showed forest loss especially on the forest edge with easy human access for both of two study areas (Mt. Bogd khan protection forest and Tuul river basin) due to forest fire followed by illegal cutting. Forest area in Tuul river has decreased by 19.1 % between 1990 and 2001. On the contrary, forest area in Mt. Bogd Khan rather increased by 7.5 % due to naturally regenerated young forest. This shows the important role of appropriate protection area as well as the rehabilitation of devastated land for the conservation of forest ecosystem in a country where restoration in difficult due to harsh climatic conditions.

요약

몽골 환경부 통계에 따르면 몽골의 전체 산림면적은 지난 20여년간 120만 ha (연간 6만 ha)가 감소한 것으로 나타났다. 몽골의 토지피복평가 및 모니터링에 관한 UNEP의 보고서(UNEP, 1998)에서는 몽골지역 임상의 변화를 야기하는 주된 원인을 산불로 보고 있다. 몽골의 극히 적은 강수량이 산불의 위험도를 증가시키는 요인이기는 하지만 산불원인의 90%는 지역주민의 경제활동과 관련되어 있다. 위성영상과 현지조사를 병행하여 보그드 한 산림보호지역과 툴 강 유역의 산림변화를 분석한 결과 두 지역 모두 사람이 접근하기 쉬운

임연부에서 산림의 훼손이 나타났다. 툴 강 유역의 산림의 1990년에서 2001년 사이에 약 19.1% 가 감소한 것으로 나타났다. 반면 보그드 한 지역의 산림은 천연갱신된 유령림으로 인해 7.5%가 증가하였다. 이러한 결과는 극심한 기후 조건으로 인해 복원이 어려운 국가의 경우 황폐지 조림 못지않게 적절한 보호 지역의 역할이 중요함을 단적으로 보여준다.

서론(Introduction)

몽골 환경부 통계에 따르면 몽골의 전체 산림면적은 지난 20여년간 120만 ha (연간 6만 ha)가 감소한 것으로 나타났다. 몽골의 토지피복평가 및 모니터링에 관한 UNEP의 보고서(UNEP, 1998)에서는 몽골지역 임상의 변화를 야기하는 주된 원인을 산불로 보고 있다. 몽골의 극히 적은 강수량이 산불의 위험도를 증가시키는 요인이기는 하지만 산불원인의 90%는 지역주민의 경제활동과 관련되어 있다. 그러나, 산불 외에도 지역에 따라서는 벌채 및 과도한 방목 등의 원인으로 장기간에 걸쳐 상당한 면적의 반 건조지역의 관목림을 포함한 산림지역이 초지 및 황폐지로 전환되었으며, 현 시점에도 이러한 변화는 계속 되고 있다. 또한 몽골에서의 산림파괴는 극히 적은 강수량, 긴 겨울 등의 극심한 기후조건과 맞물려 사막화를 가속화하고 있으며 지역주민의 생활에 위협 요인이 되고 있다. 본 연구에서는 비록 과거 영상이기는 하나 몽골의 산림보호지역과 비보호지역의 산림피복변화를 살펴보고자 하였다. .

재료 및 방법(Methodology)

2003년 발생한 Landsat 7의 scan line corrector 고장 이후로 활용도가 낮아지기는 하였으나 대면적을 대상으로 상대적으로 높은 해상도를 지닌 Landsat 영상은 경년변화 탐지에 매우 적합하다. 본 연구에선 자원탐사위성인 Landsat 5(TM)의 1990년 9월 10일에 촬영된 131-26, 131-27(Path-Row) 지역, Landsat 7(ETM+)의 2001년 8월 31일에 촬영된 동일지역의 서로 다른 두 시기의 영상을 이용하였으며 중점 연구대상지의 지도 및 임상도 등의 참조자료를 이용하였다. 중점 연구대상지의 식생변화 탐지를 위하여 본 연구에서는 식생의 변화 탐지에 보다 유용한 것으로 알려진 Tasseled Cap 변환 기법을 이용하였으며 정규식생지수(NDVI)의 비교를 통하여 산림의 변화양상을 파악하고자 하였다. 또 현지조사를 통해 ground truth를 확보함으로써 분석의 정확도를 높이고자 하였다.

결과 및 고찰(Results and Discussion)

1999-2007년 각종 참조자료와의 비교를 통해 다시 무감독 분류 및 감독 분류를 실시하고 산림지역만을 추출하여 1990년의 산림지역과 2001년의 산림지역의 차이를 분석한 결과는 표 1.에 나타나 있다.

표 1. 1990 - 2001년 연구대상지역의 산림면적 변화 단위: (ha)

지역 연도	1990	2001	증감
Mt. Bogd Khan	19,706	21,125	+ 1,419(7.5%)
Tuul river basin	15,494	12,530	- 2,964(19.1%)

분석 결과 Mt. Bogd Khan 지역은 1990년에 비해 오히려 약 7.5% 정도 산림면적이 증가한 것으로 나타났는데 이러한 결과는 Mt. Bogd Khan 지역이 절대보전지역으로서 타 지역에 비해 잘 보전되었음을 보여주고 있다. 그러나 산림지역의 임연부에서는 비록 소규모이기는 하나 산불과 벌채등의 훼손이 일어난 것으로 나타났다. 현장조사 결과를 토대로 하여 분석한 결과 훼손지의 규모는 그리 크지 않은 것으로 나타났으며 훼손의 주 원인은 산불이 발생한 후의 벌채 또는 임연부에서의 소규모 벌채인 것으로 판단되었다. 실제적으로 산림면적이 증가한 것으로 분석된 원인은 과거에 임내에 존재하던 유령림의 수고 생장 및 직경의 진계 생장, 수관의 밀도 증가 및 상층을 우점하는 중 장령림의 수관울폐도 증가에서 기인한 것으로 판단된다. Tuul 강 상류지역의 경우 상당부분의 산림이 초지 및 나지로 변화하여 지속적으로 훼손되어 온 것으로 판단되었다. 특히 임연부의 산림훼손이 심각한 것으로 나타났으며 현재 생육하고 있는 임분들 역시 활력도가 낮아진 것으로 나타나 산림지역의 보호 및 조림을 통한 복원이 시급한 것으로 판단되었다. 본 연구결과는 몽골과 같이 극심한 기후조건으로 인해 산림의 복원이 어려운 국가에서는 적절한 보전지역의 설정 및 관리가 조림 등을 통한 복원 못지 않게 중요한 일임을 단적으로 시사한다.

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Idea of Rifling Application of Water Mist Nozzle for Forest Fire Extinguishing

산불진화용 미분무수 노즐의 강선 적용에 관한 아이디어

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Abstract

This Study is about application idea of rifling groove onto the inner surface of water mist nozzle for extinguishing forest fire. This apparatus has been already adopted to the linear reactor of Supercritical Water Saccharification Pilot Plant, KFRI.

These experiments have suggested somewhat meaningful advantages as to spreadability, driving distance and so on of firefighting water.

요약

본 연구는 국립산림과학원 바이오에너지연구과가 연구하고 있는 초임계수 산화분해장치의 반응기에 채용되었던 내부 강선(腔線; Rifling)에 관련된 연구를 응용한 것으로서 미분무수 소화장비의 핵심부품인 분무노즐의 설계에 아이디어를 제공하고자 하는 것이다. 실험결과 적어도 미분무수 노즐 내부의 설계형태를 변화시키는 것만으로도 방화수의 퍼짐성과 도달거리에 있어서 어느 정도 유의한 효과를 거둘 수 있음을 보이고 있다.

서론 (Introduction)

미분무수(微噴霧水; Water Mist fire Extinguishing) 소화설비는 미세한 수적(水滴; 물방울)으로 이루어진 분무를 소화(消火)에 활용하는 것으로서 과거에는 국제해사기구의 노력에 힘입어 상업용 선박 등에 주로 사용되던 것이 최근에는 전산실 · 엔진룸 · 주방과 같은 육상시설에서도 많이 도입되고 있다.

한편 미분무수 소화설비 혹은 장비가 산불진화용으로 사용되는 예는 많이 알려지지 않고 있는데 이는 미분무수 진화가 제한된 공간에서의 진압방법으로 발전된데다가 여타 화재와는 다른 '산불의 고유한 특성과 진화방법'에 따른 것이라고 생각할 수 있다. 여기에서는 미분무수 설비의 소화성능 변수에 대한 깊은 고찰보다는 이에 응용할 수 있는 기계적인 아이디어를 살펴보고자 한다.

연구방법 (Methodology)

미분무수 소화설비라 함은 고압으로 가압된 물이 헤드(Head)를 통하여 분사되어 소화하는 소화설비를 말하는데 분무 소화설비는 미세한 수적(水滴)이 화염 및 주변 기상의 온도에 의해 급격하게 증발하고 팽창하면서 열을 흡수하고 화원(火源) 주변을 적셔 냉각을 하는 방식이다.

미분무수 방식은 최소설계압력에서 헤드로부터 방출되는 방화수(防火水) 입자 중 99%의 크기가 400micrometer 이하로 분무되는 소화 방식을 말하고 미분무수노즐(Water Mist Nozzle)은 미분무수를 만들 수 있도록 설계된 하나 이상의 오리피스(Orifice)를 갖고 있는 특수목적 기구를 이르는데 특히 미분무 소화설비는 수적을 급속히 체적 팽창시켜 화원 주변의 산소를 밀어내고 연료-산소 혼합기의 농도를 떨어뜨려 열복사 피드백을 차단하면서 소화를 진행하는 냉각-질식효과를 가지고 있다고 알려져 있다. 여기에서 이러한 소화원리에 영향을 미치는 가장 중요한 변수로 열전달 표면적의 증가와 이에 따른 열전달 및 증발 현상에 영향을 주는 수적의 크기 분포와 분무밀도, 분무 운동량 등을 들 수 있다.

이러한 미분무 소화설비는 미분무 노즐, 압력용기, 섹션 밸브, 펌프 유니트 등으로 구성되는데 특히 핵심부품인 미분무 노즐은 IMO Res. MSC. 265(84)에 따라 노즐 성능시험 및 소화 성능시험을 통해 형식승인을 얻어야 하고 특히 Back Draft 또는 Flashover 등의 현상을 막을 수 있도록 채용에 있어서 적절한 노즐 형태와 가압 방식의 선택이 필요하다

한편 국립산림과학원 바이오에너지연구과는 초임계 상태에 도달한 고온 고압의 물(Waer)을 이용하여 목분 슬러리(Slurry)를 분해하는 반응기를 보유하고 있는데 이러한 반응기는 선형, 반구형, 원형 튜브형 등 다양한 형태가 있는 바, 특히 선형의 반응기에 있어서는 고온고압의 물리상태에서 입자(Granule) 형태를 지닌 유체가 반응기 내부를 난류확산(Turbulent Diffusion) 등의 거부 거동이 없이 매우 신속하게 이동하여야 하므로 그 내부 형태가 중요하다.

이러한 거동을 해결하기 위하여 국립산림과학원이 출원하여 등록한 대한민국 특허 제10-0904561에서는 선형의 반응기 내부에 특수한 강선(腔線; Rifling)을 넣어서 목분 슬러리를 비롯한 매우 작은 수적들과 내부 유체를 효과적으로 배출하는 방법을 제시하고 있는데, 여기에서 초임계 상태에 도달한 물이 강선반응기를 통과하여 고압상태에서 해압되어 대기중으로 배출되는 물리거동은 산불진화용 호스 노즐이 분무상태의 소화제를 토출하는 것과 비슷한 양상을 보이는데 특히 전술한 소화원리에 영향을 미치는 중요변수 등이 유사하게 거론될 수 있다.

따라서 이 연구에서는 이들 방식의 차이점과 개별 특성을 모두 고려하지는 않고, 다만 대기중에 미분무수가 노출되기 직전까지의 도관(Pipe)의 강선(Rifling)과 그 회전에 따른 분사압력, 방출거리, 분무량의 영향을 살펴보았다.

아래 Fig.1은 일반 미분무 노즐과 시험용으로 제작한 강선형 미분무 노즐로서, 특히 Fig.2에는 내부에 강선을 채용한 미분무 노즐의 내부 구조 모식을 표현하였다. 또한 Fig.3은 각 노즐의 실제 단면을 보이고 있다.

Fig.1. 강선형 미분무 노즐(상)과 일반 미분무 노즐(하)

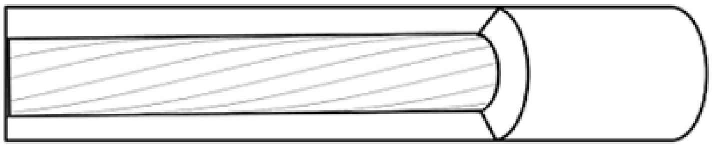

Fig.2. 강선형 미분무 노즐의 내부 형태 모식

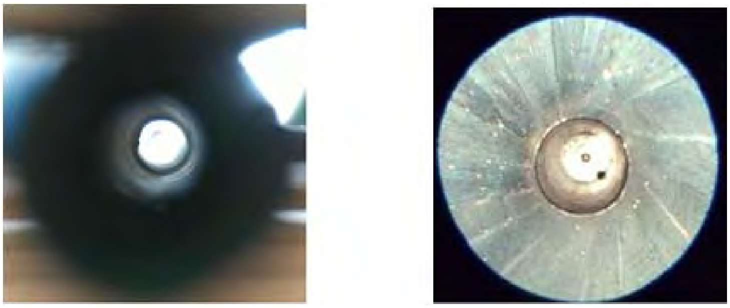

Fig.3. 일반형 미분무 노즐 내부 단면(좌)와 강선형 미분무 노즐 내부 단면(우)

강선은 노즐의 내부에 새겨진 나선형의 홈(Groove)으로서 고압으로 토출되는 방화수가 화원(火源)을 겨냥하여 대기중으로 통과하도록 유선(流線)을 만드는 역할을 하는데, 이때 강선에서 튀어나온 부분인 강선등(Land)과 들어간 부분인 강선홈(Groove)의 형태는 직선형, 회전형 등 몇 가지의 변형이 있을 수 있고 강선등과 강선홈의 절삭높이의 차이는 가공 전의 노즐 내부의 직경에 따라 변이가 있을 수 있다.

강선의 형태는 4조 우선(4/Right, 4R), 4조 좌선(4/Left, 4L), 6조 우선(6/Right, 6R), 6조 좌선(6/Left, 6L), 8조 우선(8/Right, 8R), 8조 좌선(8/Left, 8L) 등 다양하게 시도될 수 있는 바, 강선의 회전정도(The Rate of Twist)를 이르는 강선 회전량(Rifle Twist)은 Emanuel G. Greenhill의 ‘강선 회전량에 대한 경험식(일명 Greenhill Formula)’을 적용하였다.

$$\text{강선회전량 (Rifle Twist)} = \frac{150 \times Bd}{(Bl/Bd)}$$

Bd: 유속(流線束)의 지름. 곧 반응기 내부의 지름. 단위는 인치(Inch).

Bl: 반응기 내부의 길이. 단위는 인치(Inch).

반응기의 내부의 연마, 곧 리밍(Reamming)은 토출되는 미분무수의 마찰압력에 의 하여도 강선등과 강선홈이 손상되지 않는 보통 수준인 일반 총강(銃腔)의 연마 수준으로 하였다. 분사압력은 순수한 물을 방화수로 사용하여

토출압 300bar 이상의 환경에서 압력을 점진적으로 높여가며 비거리(飛距離; Driving Distance)를 측정하는 방식으로 실험하였다. Fig.4는 토출압을 조절하기 위해 사용한 고압펌프 FELUWA hose diaphragm piston pump (Type: ZGL 30/130 - K 36 – SM 235/190 HD)를 보인 것이고 Fig.5는 강선 및 리밍 작업을 보인 것이다.

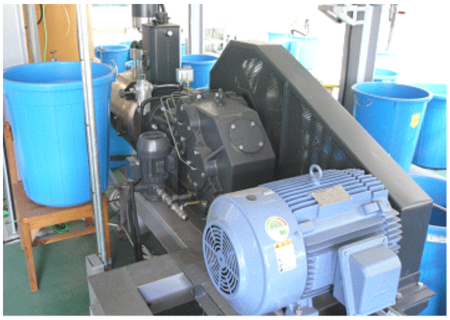

Fig.4. 방화수 토출 펌프

Fig.5. 강선 및 리밍 작업

결과 및 고찰 (Results and Discussion)

산불현장의 환경과 산불진화의 방법은 그 양상이 매우 복잡다단하지만 만약 근거리의 지표화나 지중화의 경우 진압을 하기 위한 방화수의 살포방식에서는 방화수의 토출 압력과 퍼짐성(Spreadability)이 중요하다고 할 것이다.

이런 측면을 고려할 때 기본적으로 일반적인 미분무 노즐과 4조 우선 (4/Right, 4R) 강선을 채용한 미분무노즐의 방화수 토출압과 비거리, 그리고 발사형태(Parabolic Shape)을 살펴볼 수 있을 것이다.

아래 Fig.6은 각 노즐을 사용했을 경우의 발사형태를 나타낸 것이고 Fig.7은 각 노즐의 토출압과 미분무 수적의 최대 도달 비거리를 나타낸 것이다.

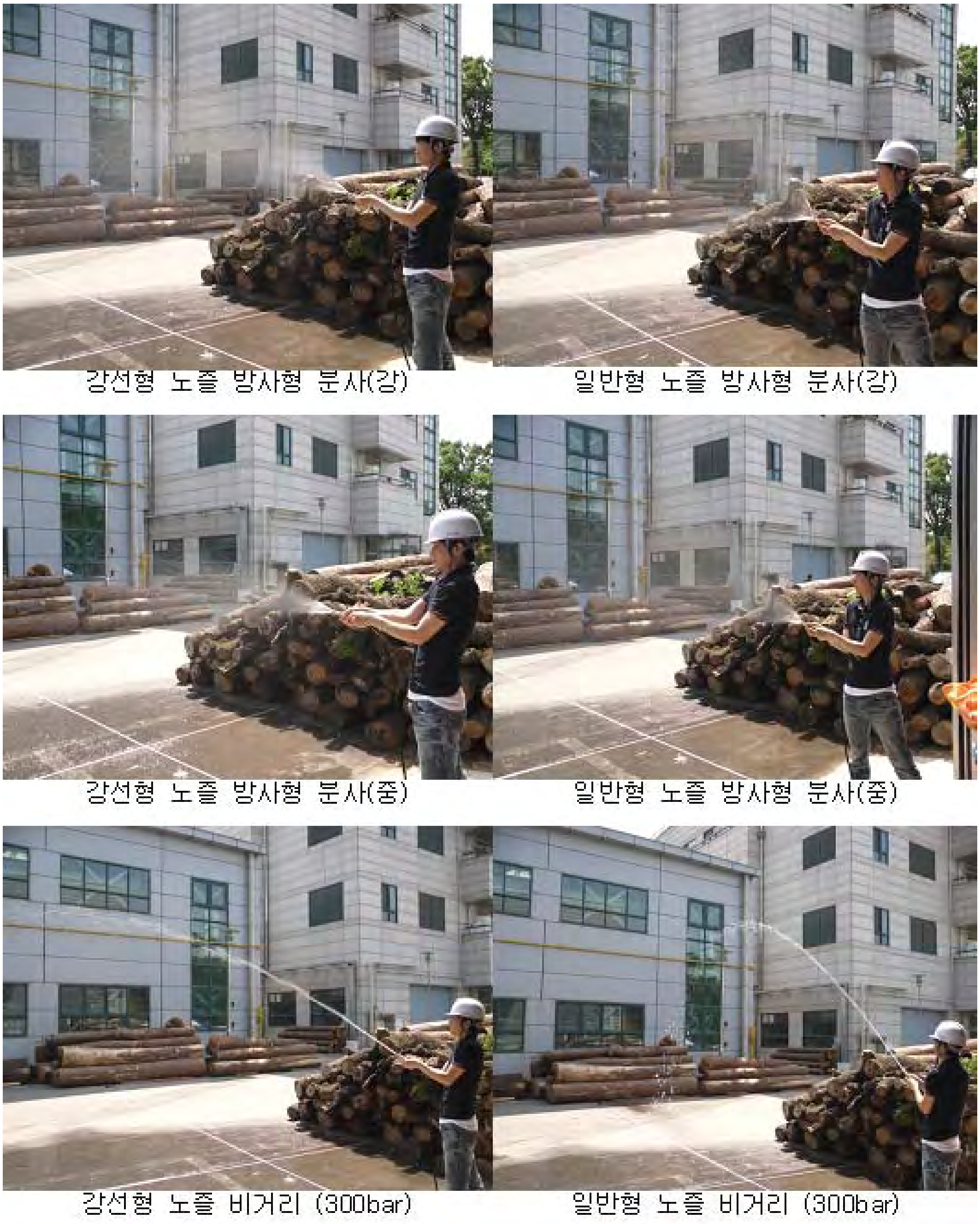

Fig.6. 강선형 노즐 사용(좌)와 일반형 노즐 사용(우)

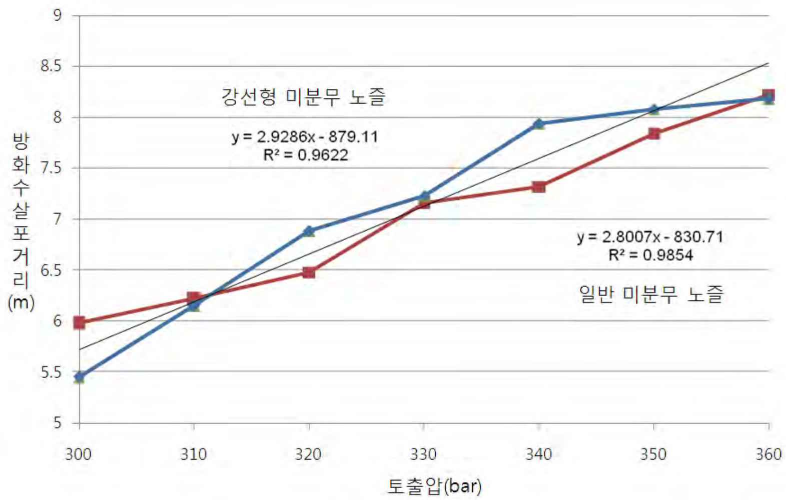

Fig.7. 토출압 변화에 따른 각 미분무수 노즐 수적의 최대 도달거리

이는 실제 산불진화 현장에서 사용하는 기계화 산불진화시스템에 적용한 결과는 아니지만 적어도 미분무 소화설비에 있어서 미분무 노즐 내부의 설계형태를 변화시키는 것 만으로도 어느 정도 유의한 효과를 거둘 수 있을 것이라는 단서를 제공하고 있다.

추후 심도있는 연구가 진행된다면 각 산불의 형태에 따른 효과적이고 적절한, 보다 발전된 형태의 미분무 노즐의 설계가 가능할 것으로 기대한다.

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Effects of Forest Fire on the Water Quality in Forest Catchments

산림유역에서 산불이 계류수질에 미치는 영향

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Abstract

This study was conducted to investigate the effects of forest fire on the water quality. The burned catchment had been damaged by forest fire broken out in April, 2000. An unburned catchment was selected to compare with the burned catchment. Water quality monitoring had conducted from 2000 to 2005, and monitoring parameters were BOD, COD, TN, TP, Cl^-, NO_3^-, Na^+, Mg^{2+} and SS.

The periodic mean concentrations of each water quality parameters measured in the burned catchment were higher than those in the unburned catchment during the whole experimental period. Especially, there were big differences between the periodic mean concentrations of TN, TP, NO_3^- and SS under the burned and unburned catchment. Also, there were wide differences between mean concentrations of each parameter under the burned and unburned catchment in 2000. However, those differences were smaller in a lapse of time. In particular, there weren't distinctive differences between mean concentrations of each parameter under the burned catchment and those under the unburned catchment..

요약

본 연구는 2000년 4월 산불이 발생한 강원도 삼척시 근덕면 일대의 산불유역을 대상으로 산불에 따른 물환경의 변화를 밝힘으로써 산불발생지역의 물환경 보전대책 수립을 위한 자료를 제공하고자 수행하였다. 연구를 수행하기 위하여 산불발생유역과 산불비발생유역의 각 유역출구에서 2000년부터 2005년까지 계류수질 변화를 모니터링 하였다.

모든 수질인자들의 평균 농도는 산불비발생유역에 비해 산불발생유역이 높아 산불로 인해 수질이 악화된 것으로 판단되며, 이중 전질소(TN), 총인(TP),

NO_3^-, 부유물질량(SS)의 농도가 현저하게 증가하였다. 또한, 계류수질의 경시적 변화를 분석한 결과, 생물화학적 산소요구량(BOD)과 화학적 산소요구량(COD)은 산불발생 후 4개월이 경과한 8월부터 두 지역간에 차이가 거의 없는 것으로 나타나 산불에 의해 교란되었던 계류수질이 산불발생 후 4개월이 경과한 시점에서 뚜렷하게 안정화되는 것으로 분석되었다.

서론(Introduction)

2000년에 동해안에 발생된 산불로 강원도 고성군, 강릉시, 동해시, 삼척시 및 경상북도 울진군에 걸쳐 23,448ha의 산림이 피해를 입었다. 이는 서울 여의도 면적의 78배에 이르는 막대한 면적으로 우리나라 총 산림면적의 0.36%에 이른다. 이들 5개 지역 가운데 삼척지역이 16,751ha로 가장 피해가 컸다(임업연구원, 2000; 이경재, 2000; 정연숙 등, 2000a; 2000b).

본 연구는 강원도 삼척시에 위치한 산불발생유역과 산불비발생유역의 계류수질 변화를 조사, 분석함으로써 산불에 따른 물환경 변화 특성을 구명하고, 산불발생유역의 물 환경 보전대책수립을 위한 자료를 확보하고자 수행하였다.

재료 및 방법(Methodology)

산불에 의한 물환경 변화를 구명하기 위하여 강원도 삼척시 근덕면 궁촌리에 소재한 산불발생유역과 개산리에 소재한 산불비발생유역을 조사유역으로 선정하였다 (Figure 1). 산불발생유역은 유역면적이 61ha로 2000년 4월 7일부터 15일까지 9일간 삼척시 근덕면 궁촌리 일대에 발생한 산불로 인하여 13,033ha의 산림피해를 받은 산불지역의 일부이고, 산불비발생유역은 삼척시 노곡면 개산리의 일부 유역으로 유역면적은 392ha이다(Figure 2). 두지역의 모암은 화강편마암이었으며, 산불비발생유역의 임상은 침엽수 Ⅲ~Ⅳ영급이었다. 경사는 산불비발생유역이 5~30°이었으며, 산불발생유역은 10~25°이었다.

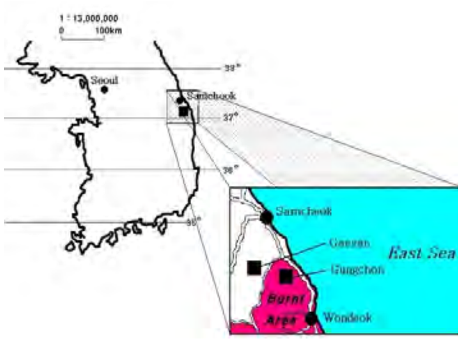

Figure 1. The location of experimental catchments.

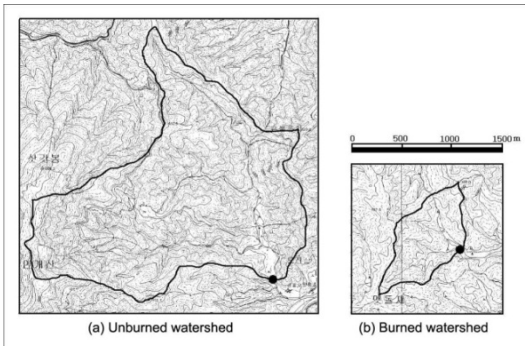

Figure2. Topographic maps of experimental catchments.

산불에 따른 계류수질 변화를 구명하기 위하여 산불발생유역 및 산불비발생유역의 각 유역출구에서 2000년부터 2005년까지 계류수질 모니터링을 실시하였다. 생물화학적 산소요구량(BOD), 화학적 산소요구량(COD), 전질소(TN), 총인(TP), 양이온(Na^+, Mg^{2+}) 및 음이온(Cl^-, NO_3^-), 부유물질량(SS) 등의 분석을 위해 시료를 Ice Box에 보관한 후 실험실에 가져와 0.45μm의 필터에 각각 2회 통과시킨 후 양이온 중 Na^+는 Frame Photometer로, Mg^{2+}는 EDTA적정법으로 분석하였다. Cl^-, NO_3^-은 Ion Chromatography로 분석하였다. 부유물질은 강우시와 강우 직후에 채취한 시료를 실험실에 가져와 200㎖의 시료에 대해 지름 47mm의 여과지(GF/C)로 여과한 다음 오븐에 넣어 105℃에서 2시간 건조시킨 후 그 질량차이를 측정하여 농도를 계산하였다.

결과 및 고찰(Results and Discussion)

2000년 6월부터 9월까지 4개월간 산불발생유역과 산불비발생유역(대조유역 I)에서 36차례에 걸쳐 측정한 생물화학적 산소요구량(BOD), 화학적 산소요구량(COD), 전질소(TN), 총인(TP), 양이온(Na^+, Mg^{2+}) 및 음이온(Cl^-, NO_3^-), 부유물질(SS)을 분석한 결과는 Table 1과 같다.

Table 1. Comparisons between water quality of the burned and unburned catchment in 2000.

Item	Burned catchment	Unburned catchment
	Average (Min.~Max) **(㎎/ℓ)**	Average (Min.~Max) **(㎎/ℓ)**
BOD	0.85 (0.00~3.04)	0.69 (0.00~2.62)
COD	6.43 (2.60~18.62)	3.07 (0.60~6.91)
TN	3.10 (0.60~11.28)	0.91 (0.05~3.82)
TP	0.08 (0.01~11.28)	0.02 (0.00~0.06)
Cl^-	6.71 (2.34~8.97)	5.09 (1.98~8.19)
NO_3^-	1.17 (0.13~1.94)	0.36 (0.05~0.63)
Na^+	7.71 (5.29~11.84)	5.83 (4.07~8.20)
Mg^{2+}	2.27 (0.70~8.78)	1.90 (0.89~5.09)
SS	20.92 (1.90~288.50)	1.59 (0.00~8.93)

Table 1과 같이 산불이 발생한 지역에서 계류수의 BOD, COD, TN, TP, 양이온 및 음이온, 부유물질농도는 강우와 함께 임지로부터 계류로 유입되는 유출물에 의한 영향을 많이 받는 것으로 나타났다. 측정기간 동안 생물화학적산소요구량(BOD)은 산불발생유역에서 평균 0.85(0~3.04)㎎/ℓ, 산불비발생유역에서 평균 0.69(0~2.62)㎎/ℓ로 산불발생유역이 산불비발생유역에 비해 다소 높은 농도를 보였으나, 두 유역 모두 하천수질환경기준 상수원수 1급수의 범위 내에 포함되어 오염되지 않은 청정한 산림 내 계류수를 나타내었다. 그러나 측정기간 동안의 화학적 산소요구량(COD)은 산불발생유역에서 평균 6.43(2.60~18.62)㎎/ℓ, 산불비발생유역에서 평균 3.07(0.60~6.91)㎎/ℓ로 산불발생유역이 산불비발생유역 보다 평균 약 2.1배 높아 수질이 악화된 것으로 분석되었는데, 이는 산불로 인하여 재 등이 강우와 함께 계류로 유입되어 기인한 결과로 판단된다). 또한, 총질소는 산불발생유역에서 평균 3.10(0.60~11.28)㎎/ℓ로 산불비발생유역에서의 평균 0.91(0.05~3.82)㎎/ℓ의 약 3.4배에 달하였으며, 총인은 산불발생유역에서 평균 0.08(0.01~0.57)㎎/ℓ로, 산불비발생유역 평균 0.02(0~0.06)㎎/ℓ의 4배로써 산지 사면에서 유출되어 계류로 유입되는 총질소, 총인의 양이 증가하여 계류수질이 악화된 것으로 나타났다. 아울러 계류수질 오염의 지표라 할 수 있는 음이온 가운데 특히 개벌 등에 의해 식생이 제거되었을 때 계류로 유출되는 양이 급격히 증가하는 환경악화의 중요한 지표인 NO_3^-의 경우 측정기간 동안 산불발생유역에서는 평균 1.17(0.13~1.94)㎎/ℓ로 산불비발생유역의 0.37(0.05~0.63)㎎/ℓ에 비해 3.2배 높아 산불로 인해 계류수질이 악화되는 것으로 분석되었다.

2003년 6월과 10월, 2004년 7월과 8월, 2005년 6월에 각각 1회 실시한 산불발생유역과 산불비발생유역(대조유역 II)의 계류수질 조사 결과는 Table 2와 같다. 조사유역 모두 '먹는 물 수질기준' 및 '하천 수질환경기준 Ⅰ급수' 범위 이내를 나타냈다(pH, DO, Cl^-, SO_4^{2-}). 그러나 Cl^-, Na^+ 이온 농도는 산불발생유역이 산불비발생유역보다 다소 높게 나타났는데, 이는 각 연도별 유사한 경향으로 산불발생유역이 해안에 인접해 있어 해풍과 함께 해수 속의 염분이 유입되었기 때문인 것으로 판단된다. 또한, 전기전도도(EC) 역시 산불발생유역이 산불비발생유역보다 높게 나타났다.

Table 2. Comparisons between water quality of the burned and unburned catchment during 2003 to 2005.

	Year	pH	EC (μS/㎝)	DO (㎎/ℓ)	Cl^-	NO_3^-	SO_4^{2-}	Na^+	NH_4^+	K^+	Mg^{2+}	Ca^{2+}
					(㎎/ℓ)							
Burned Catchment	2005	6.72	57.4	9.16	5.37	0.10	2.82	9.99	0.05	0.88	1.72	5.62
	2004	6.61	51.7	9.25	7.09	0.28	2.58	6.77	0.04	0.81	1.24	3.50
	2003	6.70	61.2	8.92	7.79	0.34	3.21	7.24	0.04	0.83	1.13	3.38
Unburned Catchment	2005	6.68	37.2	9.79	2.64	0.62	3.50	7.38	0.02	0.21	1.88	3.07
	2004	6.61	33.7	10.46	3.68	0.30	2.23	3.50	0.04	0.69	1.09	1.66
	2003	6.65	34.0	9.61	3.80	0.50	2.02	3.98	0.04	0.71	1.11	1.69
Drinking water standard		5.8~8.5	-	-	<250	<10	<200	-	-	-	-	-
River water quality standard (Ⅰ)		6.5~8.5	-	7.5<	-	-	-	-	-	-	-	-
Streamwater quality standard		5.8~8.5	<100	7.5<	<5	<10	<10	<5	<0.5	<2	<2	<10

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The Effect of Microbial Compost on Soil and Vegetation in Forest-fire Areas

미생물 퇴비가 산불 이후 토양과 식생에 미치는 효과

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Abstract

The forest located in Yongdong area has been experiencing fire repeatedly during spring dry season in Korea peninsula. A forest fire incinerates plant materials, humus, and detritus, which often cause loss of surface soil materials during rainy season. These events may be detrimental to establish a stable community structure. We studied the effect of microbial compost on vegetation reintroduction and soil properties in compost treated and non-treated plot (12m X 12m) which was set up three different sites. When we compared the soil properties, organic matter, water content, and EC were higher in compost treated plot than non-treated plot. And we found that vegetation cover and number of species were also increased in the treated plot. These results suggest that vegetations in the treated plot supplied soil organic matter whereby soil loss was decreased rather than non-treated plot. The results of soil organism activity using fluorescein diacetate (FDA) hydrolysis show that treated plot has higher microbial activity than non-treated plot, and the results of microbial biomass C also revealed that treated plot has higher biomass than non-treated plot except for Gangneung site. It was found from the results that microbial compost may be positive effect on soil stabilization and vegetation reintroduction.

요약

영동 지역 산림은 봄철 건조기 마다 산불을 자주 겪고 있다. 산불은 식물체와 다양한 토양 유기물을 태우고 이로 인해 우기에 토양 유실이 일어나게 된다(Morris SE, 1987). 이러한 과정은 군집구조 안정화에 부정적인 영향을 미치게 된다. 산불이 일어났던 세 개 지역에 미생물 퇴비 처리

방형구와 비처리 방형구(12 m X 12 m)를 설치하여 미생물 퇴비에 의한 식생 도입과 토양 환경에 미치는 영향을 연구했다. 토양 특성을 비교한 결과 유기물 함량과 수분 함량, EC 수치가 비처리구에 비해 증가한 것을 발견할 수 있었다. 식생의 경우도 처리구가 식생 피도와 종수에서 비처리구에 비해 높게 나타났다. 이는 처리구에서 식생 피복도가 높아지면서 토양 유실이 감소되어 토양 특성의 차이가 발생한 것으로 보인다. 토양 미생물 활성을 측정한 결과도 처리구가 활성이 높았으면 미생물 생물량의 경우는 강릉 지역을 제외하고 처리구가 비처리구에 비해 높았다. 위의 결과를 통해 미생물 퇴비가 토양의 안정화와 식생의 도입에 긍정적인 영향을 미쳤음을 예상할 수 있었다.

서론(Introduction)

동해안 산림은 봄철 건조기 마다 산불을 자주 겪고 있다. 또한 마사토를 기반으로 한 표토층은 산불 후 우기가 되면 토양 표면을 덮어 주는 식물층이 빈약하기 때문에 토양유출현상이 심하다. 현재까지는 주로 조림이나 자연 천이에 의존해서 자연적인 회복이 되기를 기다렸으나 조금 더 적극적인 복원 방법으로 유용한 미생물을 산불 직후 투입해 줌으로써 미생물의 균사에 의한 표토층 토양유실을 최소화하고 미생물에 의한 유기물 흡착 및 분해를 통한 토양개량으로 식물 종자의 발아 및 유식물의 생장을 촉진함으로써 산불 피해지의 조기 회복을 기대할 수 있다(Hart SC, 2005) .

재료 및 방법(Methodology)

적용한 미생물 제제는 갯벌에 서식하는 미생물인 광합성세균 (*Rhodopseudomonas palustris*), 유산균 (*Lactobacillus plantarum*), 효모 (*Saccharomyces cerevisiae*)로 이루어졌다. 고상 제제는 위의 미생물로 발효퇴비로 만든 것이다. 사용한 미생물은 그 자체가 많이 증식하는 것이 아니라 토양에 들어가면 유용 영양 염류 활용도를 높이고 자체 토양 내 유용 미생물의 활동을 촉진할 목적으로 선택하였다.

-강릉 대조 (KC), 강릉 처리 (KT) : 강원도 강릉시 사천면 청솔공원

2005년 5월 12일 남쪽 사면 12m X 12m (144m2) 지역에 액상 미생물 제제를 40L, 고상 미생물 제제를 40kg을 일차 적용하였다. 2005년 8월 20일 현장 확인 후 복원이 느린 곳에 고상 미생물 제제를 20kg 추가 처리하였다. 처리 효과를 확인하기 위해 처리구에서 왼쪽으로 10m 떨어진 곳에 동일한 면적을 대조구로 선택 하였다.

-삼척 대조 (SC), 삼척 처리 (ST) : 강원도 삼척시 길곡리

2005년 5월 12일 남쪽 사면 15m X 15m (225m2) 지역에 액상 미생물 제제를 40L, 고상 미생물 제제를 40kg을 일차 적용하였다. 2005년 8월 20일 현장 확인 후 복원이 느린 곳에 고상 미생물 제제를 20kg 추가 처리하였다. 처리 효과를 확인하기 위해 처리구에서 왼쪽으로 10m 떨어진 곳에 동일한 면적을 대조구로 선택 하였다.

-울진 대조 (UC), 울진 처리 (UT), 비산불(NF) : 경북 울진군 현종산

2007년 5월 11일 현종산 남서쪽 사면에 12m X 12m (144m2) 지역에 액상 미생물 제제 및 고상 미생물 제제를 처리구1 (UT1)에는 40kg, 40L를 각각 처리하고, 처리구2 (UT2)에는 20kg, 20L 각각 처리했다. 8월 20일 현장 확인 후 복원이 느린 곳에 고상 미생물 제제를 20 kg 추가 처리하였다. 처리 효과를 확인하기 위해 처리구에서 왼쪽으로 10m 떨어진 곳에 동일한 면적을 대조구로 선택 하였다. 또한 비산불 지역 대조를 위하여 같은 현종산 내 산불 피해를 입지 않은 소나무림을 정해서 현장 외 대조구로 활용하였다. 소나무 숲은 직경 30센티미터 내외의 성숙한 숲을 선택하였다.

결과 및 고찰(Results and Discussion)

강릉, 삼척 지역의 경우 처리구와 대조구를 비교했을 때 대부분의 토양 특성이 처리구가 대조구에 비해 양호하게 나타났다. 특히 삼척의 처리구는 대조구에 비해 토양 수분함량, 유기물 함량, EC, 양이온 값들이 높게 나타났다. 울진 지역은 비산불 지역이 산불지역에 비해 토양 특성이 양호하게 나타났으며 대조구와 처리구 간의 차이도 EC와 양이온의 경우 2배 가량 차이를 보였다 (Table 1). 이는 처리구에서 식생의 피복도가 월등히 높아 토양 유실이 감소되면서 토양 특성의 차이가 발생한 것으로 보인다.

Table 1. Soil properties in control(C) and treated (T) plot

Sampling site	Soil sample	WC (%)	OM (%)	Bulk pH	EC (us/cm)	AP (mg/g)	Mg^{2+} (mg/g)	K^{+} (mg/g)	Ca^{2+} (mg/g)
강릉	C	12.4	3.3	5.05	33.0	2.14	0.122	0.066	0.347
	T	13.2	3.7	5.01	39.8	0.78	0.428	0.165	0.395
삼척	C	11.2	3.1	5.03	37.2	0.79	0.131	0.051	0.268
	T	18.1	7.1	4.74	57.8	1.74	0.108	0.072	0.319
울진	C	31.3	8.2	5.29	49.4	0.77	0.246	0.159	0.545
	T	33.6	8.7	5.31	70.5	0.77	0.311	0.212	0.904
	NF	32.3	11.1	4.62	112.9	0.80	0.105	0.128	0.220

WC: water content, OM: organic matter, AP: available phosphate

Fluorescein diacetate hydrolysis assay를 이용해 미생물 효소 활성의 측정한 2009년 결과에서는 강릉 지역은 대조구와 처리구 간의 차이가 미미하고 삼척 지역은 처리구(ST)가 대조구에 비해 미생물 활성이 두 배 가량 높았다. 2010년의 결과도 삼척 처리구가 대조구에 비해 높은 측정값을 보였다. 울진 지역의 경우 대체로 2009년 보다 처리구가 대조구에 비해 높은 미생물 효소 활성을 보였다(Fig. 1). 이를 통해 유효 미생물의 처리와 식생의 피도 증가로 미생물 효소 활성이 높아졌음을 확인할 수 있었다. Fumigation Extraction 방법을 이용해 토양 미생물의 생물량 (microbial biomass C)을 측정 결과에서는 건조 토양 1g 당 가장 높은 microbial biomass C를 가지고 있는 토양은 비산불 지역(NF)으로 2009년과 동일했고 다음으로 울진 처리구(UC) 었다. 가장 낮은 생물량은 보인 지역은 강릉 처리구(KT)로 NF2에 비해 4배 가량 낮게 측정 되었다(Fig. 2). 토양 미생물 효소 활성은 토양 유기물 함량, 수분 함량과 높은 상관 관계를 보였으며, 토양 미생물 생물량도 유기물 함량과 높은 상관 관계를 보였다. 이상의 결과를 통해 유효 미생물 처리 지역의 식생 생육이 증가하고 피도 값이 높아짐으로 해서 토양 환경이 개선되어 미생물의 효소 활성과 생물량이 증가 된 것으로 추측할 수 있었다.

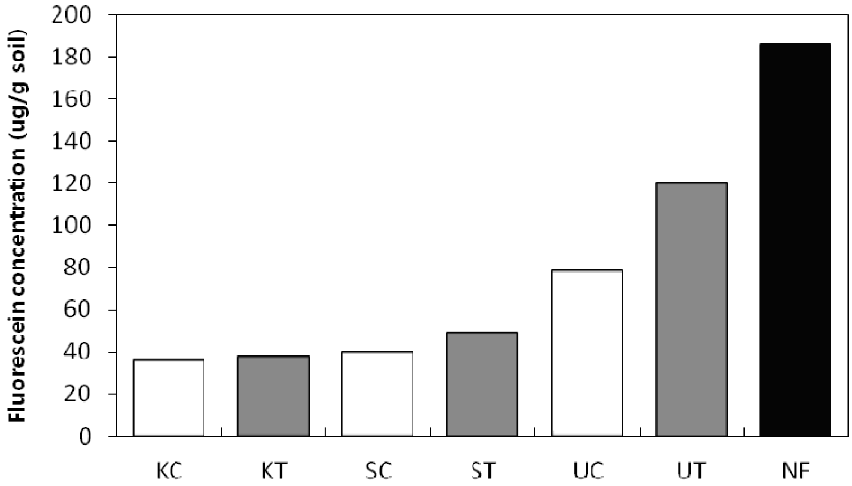

Fig. 1. Total microbial activity at each site

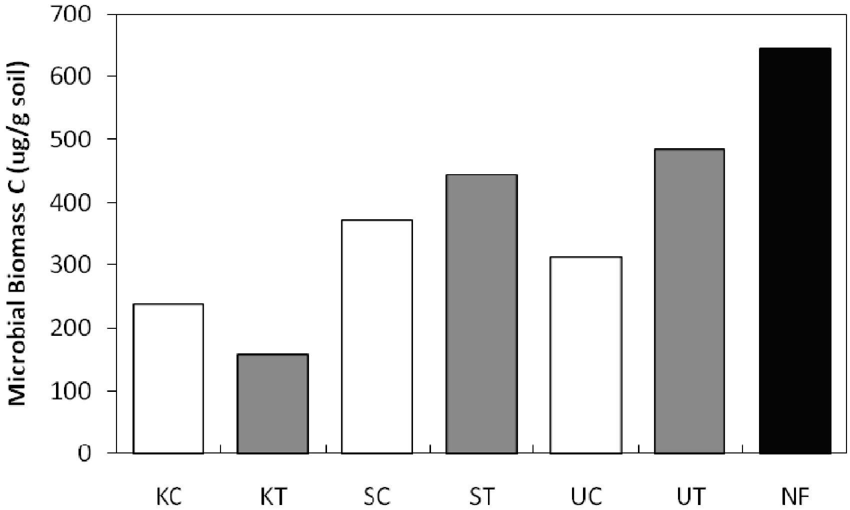

Fig. 2. Microbial Biomass C at each site

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Allocating Initial Attack Resources in the Republic of Korea with a scenario based optimization model

최적화 모델을 이용한 진화자원 배치

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Abstract

This study explores the optimal spatial allocation of initial attack resources in the Republic of Korea. We use spatially explicit GIS-based information on the ecology, fire behavior, and economic characterizations important in Korea. The data include historical fire events in the Republic of Korea from 1991 to 2009, suppression costs, and spatial information of forest fire extent. Interviews with forest managers inform the range of objective functions and policy goals we address in the decision model. Based on this information, we create a modified optimization program to explore the Korean initial attack resource allocation decisions with a range of policy goals. The disparity of optimal fire policy exists between regions depending on their own characteristics (i.e., fire behavior, terrain, budget constraints, and policy goals). We conduct sensitivity analysis by varying parameters systematically. The information about the relative importance of components of the setting helps to identify “rules of thumb” about initial attack resource allocations in particular ecological or policy settings.

Introduction

Over recent decades, large wildfires have posed significant budgetary challenges to fire management agencies charged with protecting human life, property, and natural resources from fire hazards. Since 1990, the areas burned by large wildfires have increased dramatically. For example, in the Republic of Korea, the recent fires such as the Donghae fire (2000) and the Samchuk fire (2000) in Gang-won province burned huge areas and caused substantial suppression costs and property losses. Further, the synchrony of large wildfires across broad geographic regions often contributes to budget shortfalls when suppression costs exceed the congressional funds appropriated for suppression.

Fire managers attempt to deploy suppression resources to stations and dispatch such resources to successfully contain fires before unacceptable costs and damages occur. Once a fire ignite, a strong and fast “initial attack[76] (IA)” action is most effective at containing a fire quickly and preventing it from escaping and causing substantial losses. Thus, deploying IA resources to satisfy the expected demands for fire suppression is critical to achieving the fire manager’s goal. However, IA resources are costly, so fire managers must allocate them efficiently, especially in the era of declining budgets.

In our research, the main questions are as follows:

1) How do fire managers allocate IA resources to bases efficiently within a limited budget in the Republic of Korea?
2) How do major parameters in the model (e.g., budget, dispatch rule) affect the allocation decision of IA resources?
3) What is the optimal spatial allocation of helicopters (i.e., helitack), a major resource, for IA in the Republic of Korea? How does the optimal spatial allocation of IA resources change under alternative management objectives?

The main purpose of this dissertation is to inform fire managers on how to effectively deal with changes in the suppression budget and how those changes will affect their measures of IA performance.

Method

1. Study Area

Our study area in the Republic of Korea comprises the whole landscape of the country. The forest area of the Republic of Korea is around 6.4 million ha (i.e., approximately 64 % of the total land area). Forest land is highly susceptible to forest fires because the area is currently characterized by thick growth owing to insufficient fuel treatment and its thick layer of fallen leaves catches fire and burns easily. Forest fires can spread rapidly in these mountainous areas (fires

[76] Initial attack is the action taken by fire-fighting resources that are first to arrive at a fire location.

spread much faster on steep slopes than they do on level ground). Spring is the most dangerous season (i.e., March, April, and May) because it is dry with high winds; 68% of forest fires occur in spring. As discussed, the causes of forest fires are mainly anthropogenic (KFS, 2007). Conifers cover 2.7 million ha, broad leaves 1.7 million ha, and mixed forest 1.9 million ha (KFS, 2005). Local administrative units (i.e., Si and Gun) are responsible for private forests and mountain villages in their areas, and these units regard mountain villages as an important policy arena.

2. Model

To address research questions for the Korean case study, we construct a scenario optimization model with two stages that, first, decide the amount of resources assigned to each station at the beginning of a fire season, and then, decide the amount of resources dispatched from each station to each fire during a fire day. Our optimization model employs the standard response framework, which is defined as the required amount of resources that can reach the fire within a pre-defined response time. Because the fire suppression system can limit the number of escaped fires, which is likely to be large, by detecting fires soon after they ignite and quickly dispatching an IA force, the set-covering style model is commonly adopted in IA planning (Haight and Fried 2007; MacLellan and Martell 1996).

Scenario optimization is widely used to model uncertainty in the parameters of location models by specifying a set of scenarios that represent the possible realizations of unknown parameters to determine a robust solution that can perform well across all scenarios (Haight and Fried 2007). In our optimization model, data include the locations of fire stations and possible locations of fires along with times required for travel between stations and fires. Ignition uncertainty is characterized by a set of fire scenarios, each listing the location and intensity of fires that could occur in a single day.

To construct the Korean fire scenarios, we use the developed stochastic Korean fire simulation model (Lee et al. 2011). This simulation model includes fire occurrence modules for generating fire scenarios and contains random variables for whether and how many fires occur on a given day, along with the location and the ignition time for each fire. We use the Korean fire simulation model to generate fire scenarios across the Republic of Korea forest areas during a fire season. Each scenario represents a day in which a combination of fire count, location, ignition time and behavior (e.g., rate of spread) occur. Using these fire scenarios, we construct a scenario-based optimization program to explore Korean IA resource allocation decisions with a range of policy goals.

The parameters of the fire scenarios in the optimization model are derived from information in the fire days obtained from the stochastic simulation. Each fire scenario represents a single fire day and includes a list of fire locations where fires occur along with the number of helicopters required in the standard response to each fire. Through the cluster analysis that uses GIS to detect spatial patterns of forest fire, Lee and Lee (2009) classify administrative district into 5 clusters by fire susceptibility. We assume that the number of helicopters required at a fire location is an increasing function of fire cluster level. The number of helicopters required in the standard responses, by cluster, is decided by the estimated mean number of helicopters deployed, using historical data for 19 years (MacLellan and Martell 1996).

The objective of our optimization model is to minimize fire-related suppression costs and losses subject to the requirement that expected fires receive a standard response. Using this optimization model, we investigate the spatially optimal allocation of IA resources such as helicopters among 9 stations administered by the KFS across a heterogeneous landscape in the Republic of Korea with two targeting goals: population centers and important ecological locations (i.e., endangered species habitats). For the analysis, we will construct a spatially explicit optimization model that accounts for all potential fire areas by minimum administrative unit (i.e., 225 Si, Gu, and Gun in about a 10 mile × 10 mile area) in the landscape using GIS. To our knowledge, no study has yet focused on the problems of the deployment and dispatch of IA resources in the Republic of Korea.

Korean Initial Helitack Model

Our initial helitack model is a mixed-integer programming model that specifies how many helicopters to deploy at each helicopter base in the Republic of Korea and how those helicopters satisfy daily helicopter demands across multiple fire locations efficiently.

Model Assumptions

Our model is based on several simplifying assumptions.

(1) The fireload index in each fire day is independent of its value on the previous day. Although the current fire and its intensity can affect future fire events in practice, we assume that the fireload index in each fire scenario is unrelated to another scenario.

(2) Representative Fire Locations (RFL) in Korean case are defined as the centers of 228 distinct administrative places, which is a minimum fire planning unit, across the Republic of Korea excluding its islands. The size of each administrative region is about 10 miles × 10 miles. Thus, a helicopter can cover the whole area of an administrative region within a few minutes.
(3) The standard response is defined as the required amount of resources that can reach the fire within 30 minutes for helicopters. In fact, helicopters require a stand-by time (e.g., 5–15 minutes). I didn't account for this stand-by time in our model.
(4) Each helicopter can respond to only one fire simultaneously on any given day. However, this assumption is later released because air resources can be used on multiple fires per day if those resources are well distributed over the course of the day.

To find the optimal spatial allocation of IA resources, the objective function and constraints can be represented mathematically as follows.

Index

i and *I* denote the index and set of kinds of fire resources;
j and *J* the index and set of fire stations;
k and *K* the index and set of potential fire locations;
s and *S* the index and set of fire scenarios.

Decision Variables

y_j = binary variable; 1 if station j is open, 0 otherwise;
x_{ij} = integer variable for amount of resource type i deployed at station j;
d_{ijks} = integer variable for amount of resource type i at station j that is dispatched to fire location k during fire day s; and
z_{ks} = binary variable; 1 if fire location k receives a standard response during fire day s; 0 otherwise.

Parameters

α = a weight ($0 \leq \alpha \leq 1$);
c_{fix} = fixed cost of opening station *j*;
c_i = annual cost of operating resource type *i*;
D_k = weight of an uncovered fire at representative fire location k;

p_s = probability that fire scenario (fire day) s occurs;
r_{isk} = amount of resource type i required at location k during fire day s;
t_{ijk} = response time of resource type i from station j to location k;
B = annual budget limit for IA;
Cap_{ij} = capacity of resource type i at station j;
T_{ik} = maximum response time of resource type i to location k; and
N_{ik} = set of stations for resource i from which resources can reach location k within the maximum response time; i.e., $N_{ik} = \{j \mid t_{ijk} < T_i\}$.

Objective Function

The objective function to be minimized is the total annual cost of operating resources and the expected number of fires that do not receive the standard response within the threshold time range (Equation 1).

$$\text{Minimize:}\alpha\left(\sum_{j\in J} c_{fix} y_j + \sum_{i\in I}\sum_{j\in J} c_i x_{ij}\right) + (1-\alpha)\sum_{s\in S} p_s \sum_{k\in K} D_k (1 - z_{ks}) \quad (1)$$

In equation 1, the first two terms indicate the fixed cost of opening stations and the total annual cost of helicopters deployed, and the last term represents the total expected number of fires that do not receive the standard response with a weight. The variables y and x are first-stage variables, as they have to be decided upon before the outcome of the stochastic variable s is observed. The variable z, which is a binary variable, is a second-stage variables, as they can be calculated after the outcome of s is known. D_k represents the protection priority to get an IA response first by weighting a high cost if a fire occurs at fire location k. p_s denotes the probability of a fire scenario. Instead of estimating the probability of the occurrence of each fire day, I assume that each scenario is equally likely (Haight and Fried 2007; MacLellan and Martell 1996).

Constraints

In inequality 2, the first constraint requires that the total annual cost of operating suppression resources for the IA is constrained to less than or equal to the budget limit.

$$\sum_{i\in I}\sum_{j\in J} c_i x_{ij} \le B \quad (2)$$

In inequality 3, the constraint represents the capacity of each station.

$$x_{ij} \leq Cap_{ij} y_j \qquad \text{for all} \quad i \in I \quad \text{and} \quad j \in J \tag{3}$$

In inequality 4, the constraint requires that the amount of resources dispatched from each station during each fire day is less than or equal to the amount of resources deployed at the station.

$$\sum_{k \in K} d_{ijks} \leq x_{ij} \qquad \text{for all} \quad i \in I, \quad j \in J \quad \text{and} \quad s \in S \tag{4}$$

In the inequality 5, the last constraint represents the condition for whether a fire receives a standard response during stage two. Whether a fire receives a standard response (zks = 1) implies that the number of each type of resource that is within the standard response time and dispatched to the fire, $\sum_{j \in N_{ik}} d_{ijks}$, is greater than or equal to the amount of resources required, riks. However, if riks = 0, there is no fire at location k during fire day s and zks = 1, thereby necessitating no resource commitment.

$$z_{ks} r_{isk} \leq \sum_{j \in N_{ik}} d_{ijks} \qquad \text{for all} \quad i \in I, \quad k \in K \quad \text{and} \quad s \in S \tag{5}$$

3. Application

Our application in the Republic of Korea focuses on the deployment of primary helicopters among 8 stations, assuming that other resources such as hand crews and fire engines are retained in their current locations. The application involves 100 fire scenario days of potential fire days, each with 10 – 20 fires occurring at different locations. For the application, we use spatially explicit GIS-based data on the ecology, fire behavior, and economic/cost characterization important in the Republic of Korea from Korea Forestry Research Institute. The information on potential fire locations is used to calculate traveling time from fire-fighting resource bases to RFLs in the Republic of Korea. Using the Korea fire simulation model of Lee et al. (2011), we generate 100 fire scenarios. We also use the current data on helitack from Forest Aviation Headquarters of Korea Forest Service (KFS) (website: www.fao.go.kr/eng/work0201.jsp). Annual costs of initial attack resources from KFS are utilized as unit costs in the application.

Results and Discussion

The curve showing the tradeoff between number of helicopters deployed and expected number of fires per 10+ fire days (days on which 10 or more fires occurred) not receiving the standard response has a convex shape where non-coverage declines at a decreasing rate as number of helicopters deployed rises (Figure 1). The points on the curve represent non-dominated solutions and their relative performance with respect to the two objectives. For each non-dominated solution, improvement in one objective cannot be achieved without simultaneously causing degradation in the value of the other objective. As a result, the points represent a frontier below which there were no better solutions.

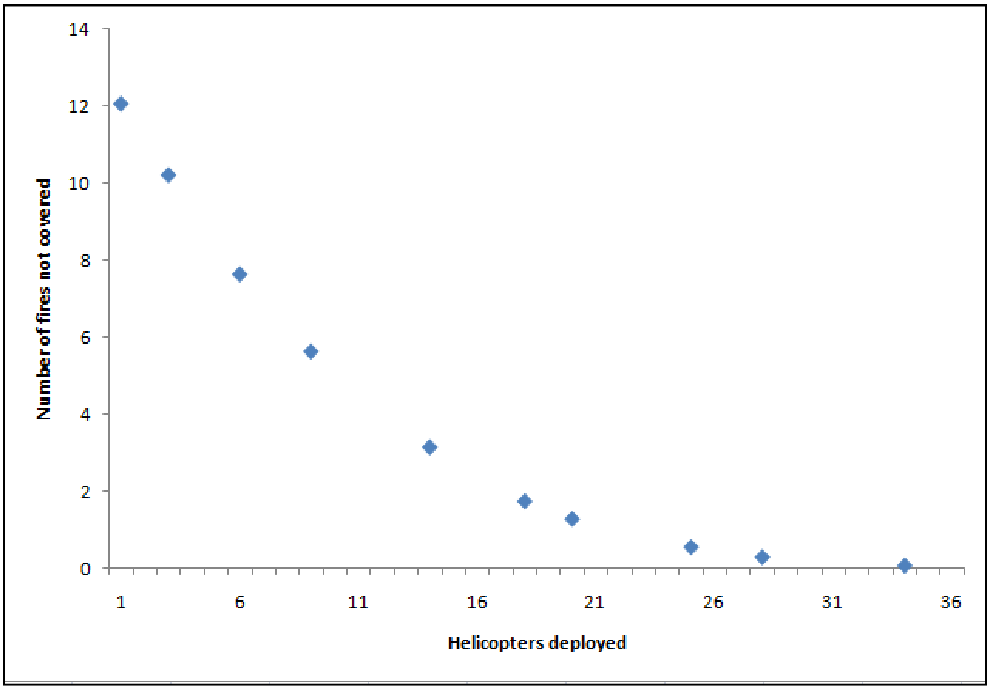

Figure 1. Tradeoff between number of helicopters deployed and expected number of fires that do not receive a standard response

The optimal deployment of helicopters depends on the objective function weight. If minimizing the number of helicopters deployed is most important (i.e., α=1), the choice is solution A in which the expected number of fires not receiving the standard response is equal to the average daily fire frequency of 12.05 (Table 1). As more weight is given to minimizing the number of uncovered fires, more helicopters are deployed (solution D), the expected number of fires left uncovered is 3.15 (25% of the average number of fires per 10+ fire day). Increasing the number of helicopters from 13 to 27 (solution I) reduces the number of uncovered fires to 0.08 (1% of the daily average). The slope of the tradeoff curve, which represents the gain in daily number of fires covered per unit increase in number of helicopters deployed, is relatively steep between solutions A and G (0.40 fires/helicopter). Between solutions G and I, the slope is relatively flat (0.06 fires/helicopter). Optimal solutions concentrate helicopters in stations that are close to RFLs with the highest fire loads or populated area (i.e., Gang-won, Kyung-buk, Kyung-nam, and Kyung-gi).

Table 1. Number of helicopters deployed per station and number of fires that do not receive a standard response from spatial optimization[a]

Case	**Num. of Helicopters**	**Num. of fires not covered**	**Helicopter Bases**							
			J1	J2	J3	J4	J5	J6	J7	J8
A	0	12.05								
B	5	7.63	1		1	1	1			1
C	8	5.63	1	1	2	1	1		1	1
D	13	3.15	2	1	3	2	1		2	2
E	17	1.75	3	2	4	2	1	1	2	2
F	19	1.29	3	3	4	2	1	1	3	2
G	24	0.56	4	3	5	3	1	3	3	2
H	27	0.3	4	4	5	3	1	4	3	3
I	33	0.08	4	5	5	5	1	4	5	4

[a] The dispatch level is defined as 5 categories: 1: 1 helicopter; 2: 1 helicopter; 3: 2 helicopters; 4: 2 helicopters; 5: 3 helicopters.

Using historical data, we conduct a sensitivity analysis on dispatch rules. The new dispatch rule is built based on the previous dispatch experiences. When we apply the new dispatch rule in our optimization model, the results show that more helicopters are required to achieve the goal to provide a standard response to a fire location quickly. For example, to reduce the number of uncovered fires to 0.08 fires (1% of the daily average), 45 helicopters should be deployed to 8 stations. Compared to the previous case (Table 1), 12 helicopters (26%) are increased to get the same results in terms of the number of uncovered fires.

With this setup, we find that up to 54 helicopters along with the other initial attack resources contain 99% of the fires. Incrementally reducing the number of primary helicopters from 54 to 14 reduces the containment rate to 25%. The number of contained fires is sensitive to where the helicopters are deployed, which shows that the spatial allocation of initial attack resources is critical to contain a fire quickly.

Table 2. Number of helicopters deployed per station and number of fires that do not receive a standard response from spatial optimization with a different dispatch rule

Case	Num. of Helicopters	Num. of fires not covered	Helicopter Bases							
			J1	J2	J3	J4	J5	J6	J7	J8
A	0	12.97								
B	14	3.25	2	2	3	2	1		2	2
C	24	0.89	4	3	5	3	1	3	2	3
D	30	0.4	3	5	6	4	2	4	3	3
E	45	0.08	4	7	8	8	3	5	6	4
F	54	0.04	8	8	8	8	4	7	6	5

[a] Based on the historical data, the dispatch level is newly defined as 5 categories: 1: 0 helicopter; 2: 1 helicopter; 3: 2 helicopters; 4: 3 helicopters; 5: 4 helicopters.

The results of this study suggest how the consideration of spatial heterogeneity with different policy preferences affects the optimal allocation of the IA resources during a fire season. Further, I expect to discern which factors (fire behavior, terrain, budget constraints, policy goals, etc.) drive differences in optimal policy between the two regions by varying parameters systematically in the sensitivity analysis. This study create a foundation for future work by establishing the application of the stochastic simulation – optimization framework to other settings, creating a platform to explore other policy goals, and building the capacity for sophisticated forest land risk management in Korea.

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Eco-toxicity of firefighting foams assessed in aquatic and semi-aquatic compact biotopes

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Abstract

Based on the observation in compact biotopes mimicking the fresh water environments and wetland, both the acute and long-term eco-toxic impacts of two fire-fighting foams were assessed. Spraying of synthetic detergent-based foam formula was shown to be more toxic compared to soap-based formula and mock water treatment.

Introduction

A variety of chemicals including foaming agents are used to aid in the protection of forest resources from the wildland fires (both woodland and grassland fires) (USDA Forest Service, 1994). The fire-fighting foams are formulations composed principally of surfactants, and act by increasing water efficiency. These chemicals are rapidly gaining acceptance as effective and efficient tools in several countries such as United State, Australia (Rawet et al., 1996; Adams and Simmons, 1999). Also, in Japan, Kitakyushu City Fire and Disaster Management Department (FDMD) and Tokyo Fire Department, followed by other local fire-related authorities nation-wide, have been using some fire-fighting foams in the urban fire controls since 1999 (Kitakyushu City Fire and Disaster Management Department, 2005). In case of wildland fire managements, much greater amounts of fire-fighting chemicals might be emitted to the environments compared to ordinary urban fire controls. Therefore possible eco-toxicities of these chemicals should be tested before designing the chemical fire fighting strategies in the fields.

However, until recent date, the potential ecological impacts of such chemicals have not been thoroughly assessed (USDA Forest Service, 1994). Therefore, certain research efforts for obtaining the reliable data of ecological risk assessments are highly required for safely managing the use of such chemicals at the ecologically acceptable range.

In Japan, possible application of such chemical foams in wildland fire managements is now being considered. Prior to actual use in the real fire-fighting field exercise in Japan, there is an emerging need for testing the impacts of these chemicals on the living organisms composing the typical landscapes or eco-systems in Japan.

For above purpose, in recent years, our group in Kitakyushu have been proposing and conducting a series of bioassays for assessing and comparing the toxicities of commercially available and newly developed fire-fighting foams and their components (chiefly synthetic and fatty acid-based detergents). The biological materials used in our recent bioassays mostly focused on the acute toxicity and biodegradability of fire-fighting chemicals include a tiny fresh water model fish, *Oryzias latipes* (Lin et al., 2006; Kawano et al., 2007a; Mizuki et al., 2007); aquatic protozoa such as *Paramecium bursaria* (Kadono et al., 2006a; Goto et al., 2007, 2008; Mizuki et al., 2007) and *Paramecium caudatum* (Kadono et al., 2006b), germinating seeds of rice plants (*Oryza sativa*. L.), a key component in the semi-aquatic landscape in Japan (Kawano et al., 2006, 2007b), and microbial system in activated sludge (Mizuki et al., 2010).

In the present report, we wish to describe our latest attempt for assessing the long-term impacts of fire-fighting foams in aquatic (fresh water environment) and semi-aquatic (wetland) eco-systems, by employing the biotope-based observation.

Experimental

Compact biotopes mimicking the aquatic and semi-aquatic eco-systems were set using plastic containers filled with water and/or soil mixture in May, 2009. Then, model aquatic organisms such as a tiny fish (*Oryzias latipes*), an aquatic microbe, green paramecia (*Paramecium bursaria*), aquatic and semiaquatic plants such as Common Water Hyacinth (*Eichhornia crassipes*) and rice plants (*Oryzias latipes*) were installed. Concomitantly, lavae of other organisms such as small sinistral, air-breathing freshwater snail (*Physella acuta*) and insects chiefly dragon flies were also installed.

Water or two fire-fighting foams (1. Phoschek, a commercially available internationally known formula containing synthetic surfactant cocktails as active ingredients, and 2. Miracle-foam, a recently released Japanese formula chiefly consisted of fatty acid salts or soaps) were sprayed above the compact biotopes in September, 2010. The latter foam formula was developed by our recent research

(Mizuki et al., 2007, 2010). Concentrations of fire-fighting agent in pre-foaming mixtures were 0.5 % (w/v) and 1 % (w/v), respectively. Onto 1 m^2 of model biotope, 3 L of water or fire-fighting mixture was sprayed (thus foam spread) after compressing the air in the fire-fighting cylinders.

Acute toxicity of fire fighting agents especially plants, fish and microbe was assessed several times within initial 2 weeks. Long-impacts of chemical treatment was assessed in April 2011, based on the changes the populations of small snails and lavae of dragon flies.

Results and discussion

The details of our results are shown on our poster. Briefly, among three different treatments, namely water, the synthetic foam (Phoschek) and the soap-based foam (Miracle-foam), acute toxicity in *Paramecium bursaria*, *Orysias latipes*, and *Eichhornia crassipes* was highest in the synthetic foam-treated biotopes. While blooms of populations in small snails (*Physella acuta*) and larvae of dragon flies were observed in water-treated and the soap-based formula-treated biotopes 7 months after the sprays, no single larva of insect or snail could be found in the synthetic foam-treated biotopes.

Our demonstration encourages more studies on the impacts of fire-fighting activities or strategies against the eco-system when applied to wildfire exercises. We are now developing a novel fire-fighting formula with less impacts on the eco-system with modified formulae of soap-based fire-fighting foam. Further tests (to be conducted partly this year) are required for materializing such ideal fire-fighting formulae.

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A Combustion Analysis of Surface Fuel Burning Experiment According to Density Variation

밀도변화에 따른 지표연료의 연소특성 분석

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Abstract

The type and intensity of Forest fire is depending on total fuel amounts contained in forest. Almost 70% of Korea is mountainous area and generally surface of these areas have many mountains and valleys. In Korea forest fire begins with surface fire near agricultural area by human error. Combustion characteristics of surface fuel according to its mass densities are the object of this paper. The fallen leaves of Quercus variabilis and Pinus densiflora, each of which is the major type of coniferous and deciduous tree respectively are used as surface fuel. The data such as combustion temperature, mass loss rate, flame height, duration of combustion and velocity of hot gas are obtained and it is to be used for the spread model and for the basic parameters for risk assessment of fire. In natural state the depth of surface fuel is generally about 5~10 cm deep and some places such as low wooded valley and crevice in the rock can have even thicker depth. In natural condition the mass of surface fuel per unit volume of cubic meters is between approximately 10~32 kg/m^3, so the densities of fuel sample in the basket are set to from 9.6 to 31.8 kg/m^3 and the diameters of the basket are changed to 20, 30, 40 and 50 cm. Almost over 150 fuel samples were burnt for data collection. Pilot ignition is carried on the top of the fuel. To find the temperature distribution from the bottom of basket up to 1.5 m, 32 thermocouples are installed in grid style and DAQ collects 32 temperature data from each thermocouple per second. As a result in case of Pinus densiflora mass loss rate, duration of flame, flame height and combustion time become larger as the mass density and diameter of basket increase, on the other hand Quercus variabilis shows saturation characteristics in mass loss rate and flame height. Velocity of hot gas is proportional to flame height.

요약

산불의 형태 및 강도는 임내의 연료물량, 수종 등에 따라 변화한다. 우리나라와 같이 경사가 급하고, 구릉지가 많은 지형에서의 산불은 대부분이 지표화로 시작하여 수관화로 전이되는 특징을 가지고 있다. 따라서 초기 연소물질인 굴참나무와 소나무 낙엽을 이용하여 밀도에 따른 지표 연료의 연소특성 분석을 하였다. 본 연구에서는 산림내 지표 연료층과 유사한 조건으로 굴참나무와 소나무 낙엽을 지름이 각각 20, 30, 40, 50cm 높이 10cm인 원통형 바스켓에 직경과 지표연료의 단위 면적당 밀도를 달리하여 5회 이상의 반복 실험을 통하여 총 160여회 이상 실험 하였다. 실험장치의 전체 시스템은 온도측정을 위하여 Ø1.6mm K-type 열전대는 총 32개를 설치하였다. 바스켓 중심바닥면, 중앙, 시료표면에 열전대 3개, 바스켓 중앙 시료표면으로부터 수직방향 25cm간격으로 열전대 6개, 바스켓 양쪽 외곽에서 수직방향 25cm간격으로 14개, 바스켓 양쪽 수평방향 25cm간격에서 8개, 주위온도 측정용 1개를 격자모양으로 설치 측정하였다. 질량감속도는 load cell을 이용 1g단위로 1초 간격으로 측정하였으며, 기체유속은 바스켓 직상부 1.5m에 Kanomax사 고온풍속계를 고정 설치하여 기체유속(0~25m/sec), 기체온도(0~500℃)를 동시에 측정하였다. 화염 높이는 캠코더로 녹화하여 1초 단위로 재생 화염의 높이를 5cm 간격으로 판독, 소염 시점까지 측정하였다. 결론적으로 침엽수종 낙엽의 경우 밀도와 지름의 증가함에 따라 질량감소속도, 화염지속시간, 화염의 높이 그리고 연소시간은 증가한 반면, 활엽수종 낙엽의 경우 질량감소속도와 화염높이는 증가하다가 감소하였으며 화염지속시간과 연소시간은 증가하였다. 또한, 기체유속 및 온도는 화염 높이가 커질수록 증가하는 경향을 나타내었다.

재료 및 방법(Methodology)

실험은 산림내 지표 연료층의 두께 및 밀도와 비슷한 조건에서 하기위해 소나무와 굴참나무 낙엽을 지름이 각각 20, 30, 40, 50cm 높이 10cm인 바스켓에 넣고, 온도분포, 질량감소속도, 화염의 높이, 연소시간, 화염지속시간, 열방출속도, 기체유속 및 온도 등의 연소 특성을 측정하였다. Table 1은 바스켓의

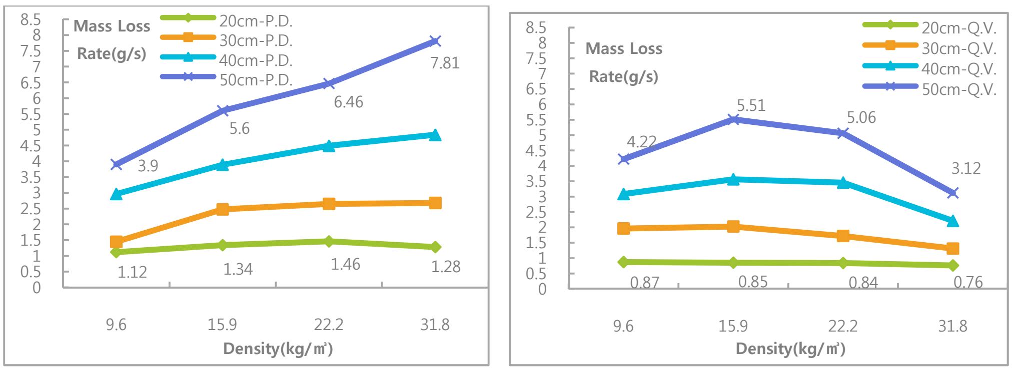
직경과 지표연료의 단위 면적당 무게를 달리하여 만든 시료의 구성표로 동일 바스켓 크기를 기준으로 하여 중량변화 따른 밀도 비는 1 : 1.7 : 2.3 : 3.3 이며, 동일 밀도의 경우 바스켓 크기에 따른 연료 중량 비는 1 : 2.25 : 4 : 6.25이다. 각 시료의 경우 5회 이상의 반복 실험을 통하여 총 160여회 이상 측정하였으며, 1초 단위로 측정 데이터를 수집한 후 분석하였다.

Table 1. Density and weight of sample filled in each basket

Diameter of basket / Density(kg/m^3)	20cm	30cm	40cm	50cm
9.6	30g	67.5g	120g	187.4g
15.9	50g	112.5g	200g	312g
22.2	70g	157.5g	280g	436.3g
31.8	100g	225g	400g	624g

결과 및 고찰(Results and Discussion)

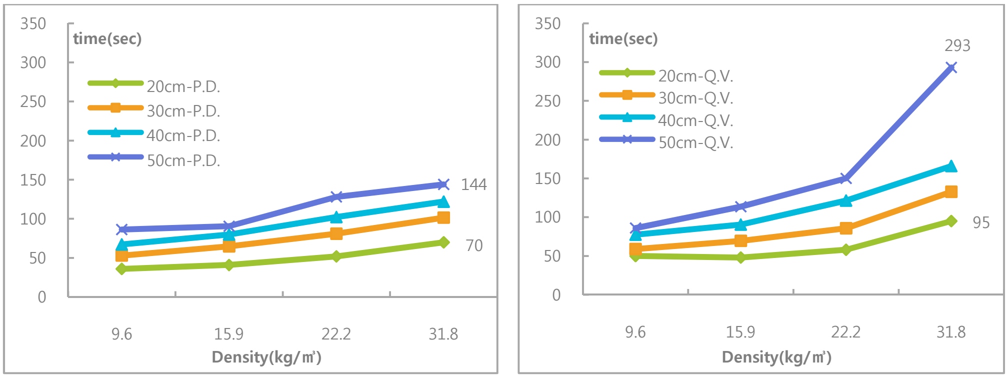
Figure 1는 소나무 낙엽과 굴참나무 낙엽에 대한 밀도 변화에 따른 MLR의 실험결과로,소나무 낙엽의 밀도 변화에 따라 MLR가 최대 약 3.5~6배정도 증가하였으며, 굴참나무 낙엽은 MLR가 최대 약 4.8~6.5배정도 증가하다가 15.9kg/㎥에서 감소하는 경향을 보이고 있다. 또한 동일한 밀도조건에서 소나무 낙엽이 굴참나무 낙엽에 비해 빠른 질량감소 속도를 나타내었으며, 이는 두 시료간의 평균 열량값 차이와 낙엽의 형태에 따라 공기 유입량의 차이에서 기인된 것으로 판단된다.



(a) Pinus densiflora (b) Quercus variabilis

Figure 1. Mass loss rate versus density change of sample.

Figure 2(a)는 소나무 낙엽의 밀도가 증가함에 따라 화염지속시간이 서서히 증가함에 비해, Figure 2(b)는 화염지속시간의 폭 차이가 크며, 특히 지름이 50cm 바스켓의 화염지속시간이 최대 약 2배(밀도 22.2kg/㎥에서 31.8kg/㎥) 증가함을 확인하였다. 특히 굴참나무 낙엽의 밀도가 증가함에 따라 화염의 높이는 감소한 반면 연소지속시간은 증가하였다. 그 이유는 밀도가 증가함에 따라 공기 유입량이 감소로 연소속도 및 화염높이가 감소하는 것으로 사료된다.



(a) Pinus densiflora (b) Quercus variabilis

Figure 2. Flame continuation time versus density change of sample.

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Changes of Fuel Consumption in forest by Thinning and Pruning

간벌 및 가지치기 방법에 따른 임내 연료량 변화

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Abstract

This study is for minimizing the damage about the large fire, and for investigating the effects of fire brake forests according to the method of thinning and pruning among silvicultural systems which are able to prepare or confront the forest fire damage. Fuel amounts of *Pinus rigida* stands treating thinning were as about half time as them of the standard plot which was not done. In case of the fuel consumption each treating plots after pruning, the standard plot was the lowest because the fuel consumption of the lower layer were increased by the thick growth of *Sasa borealis* according to treating pruning. Therefore, to reduce the fuel consumption, it has been thinking that periodical weeding on the lower layer should be needed after doing pruning. As a result of analyzing the fuel consumption of litter layer affecting a lot to breaking forest fires, the higher the intensity of thinning was, the lower the fuel consumption would be after thinning in *Pinus rigida* stands. However, the fuel consumption of litter layer after pruning in *Pinus koraiensis* stands tended to increase because of the thick growth of the lower layer.

요약

본 연구는 대형산불에 대한 피해를 극소화 시키고, 산불재해에 대비·대응할 수 있는 임업적 시업방법 중 간벌 및 가지치기 방법에 따른 내화수림대 조성효과를 구명하고자 한다. 리기다소나무림의 간벌 처리에 따른 연료량은 처리를 하지 않은 대조구보다 약 1/2정도 낮게 나타났다. 가지치기 처리 후 처

리구별 연료량은 대조구가 가장 적게 나타났는데, 이는 가지치기 처리에 따른 조릿대 밀생으로 하층 연료량 이 증가하였기 때문이다. 따라서, 연료량을 감소시키기 위해서는 가지치기 처리 후 하층의 풀베기 작업이 주기적으로 실시해야 할 것으로 사료된다. 산불발생에 큰 영향을 미치는 낙엽층의 연료량 분석결과, 리기다소나무림의 간벌처리 후 연료량은 간벌 강도가 높을수록 연료량은 낮아지는 경향이 나타났다. 그러나, 잣나무림의 가지치기 처리 후 낙엽층 연료량은 가지치기 후 하층의 밀생으로 연료량이 증가하는 경향이 나타났다.

Introduction

최근 우리나라에서도 이상고온, 건조 등 기후변화에 따른 건조일수, 산림 내 지피물 등 연소물질 증가 등으로 산불의 대형화 및 전국 동시 다발성 산불 발생이 증가하는 추세이다. 대형산불에 대한 피해를 극소화 시키고, 산불재해에 대비·대응 할 수 있는 임업적 시업방법 개발이 필요하다. 이러한 임업적 시업방법 중 내화수림대 조성은 산불발생으로 인한 피해가 큰 소나무 단순림을 대상으로 산림 내 임도나 작업로를 이용하는 방법, 주변 임상을 고려하여 침엽수와 활엽수(참나무류)가 혼효되도록 유도하는 방법, 임분을 자연지형을 이용하여 10～20m 폭으로 내화수림대를 조성하는 방법 등이 있다. 본 연구는 이러한 임업적 시업방법 중 임내 간벌 및 가지치기 방법에 따른 내화수림대 조성효과를 구명하여 대형 산불예방과 피해저감을 위한 기초자료로 활용하고자 한다.

Methodology

연구대상지는 경남 거창군 위천면 상천리(N 35°42′32.9″, E 127°48′21″)에 위치하고 있으며, 리기다소나무 조림지는 1979년 3,000본/ha을 조림하여 1991년도에 1,500/ha로 간벌을 실시 한 후 잡관목이 울폐하였으며 해발고 668m, 경사도 5～20°였다. 잣나무 조림지는 1990년도에 조림하였고 수령은 28년이며, 해발고 410m, 경사도 5～10°였다. 내화수림대 조성을 위한 임업적 시업방법은 리기다소나무(Pinus rigida, P.R.)림은 100본/ha, 200본/ha, 300본/ha으로 간벌처리하였으며, 잣나무(Pinus koraiensis, P.K.)림은 수고 대비 50%와 70% 가지치기를 실시하였다. 임내 처리별 효과를 분석하기 위하여 각각의 처리 후 임내 연료량을 분석하였다.

Results and Discussion

리기다소나무림의 간벌강도 후 처리구별 전체 연료량은 입목밀도가 높은 대조구에서 52.2ton/ha로 높게 나타났으며, T 100에서 낮게 나타났다. 하층 연료량은 대조구(31.4ton/ha)>T 300(20.6ton/ha)>T 200(18.7ton/ha)>T 100(16.6ton/ha) 순으로 나타났다. 간벌강도 처리에 따른 연료량은 처리를 하지 않은 대조구보다 약 1/2 정도 낮았다. 가지치기 처리구 별 전체 연료량은 P 50(92.2ton/ha)>P 70(87.5ton/ha)>대조구(58.7ton/ha) 순으로 대조구가 가장 적게 나타났는데, 이는 가지치기 처리에 따른 조릿대 밀생으로 인한 하층의 연료량이 증가하였다(Wang et al. 1995). 따라서, 연료량을 감소시키기 위해서는 가지치기 처리 후 주기적으로 하층의 풀베기 작업을 실시해야 할 것으로 사료된다. 산불발생에 큰 영향을 미치는 낙엽층의 연료량 분석 결과, 리기다소나무림의 간벌강도 후 연료량은 대조구(31.1ton/ha)>T 300(20.6ton/ha)>T 200(18.7ton/ha)>T 100(16.2ton/ha) 순으로, 강도가 높을수록 연료량은 낮아지는 경향이 나타났다. 잣나무림의 가지치기 후 연료량은 P 50(19.7ton/ha)>P 70(9.8ton/ha)>대조구(8.2ton/ha) 순으로, 가지치기 후 하층의 밀생으로 연료량이 증가하는 경향이 나타났다.

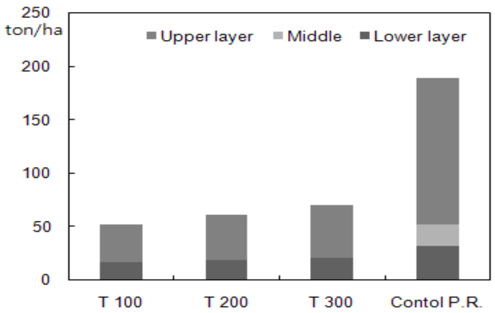

Figure 1. Fuel consumption of layers at pruning plots

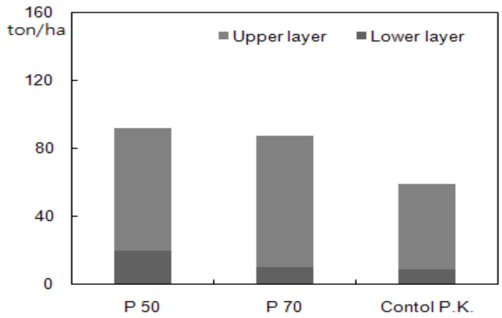

Figure 2. Fuel consumption of layers at pruning plots

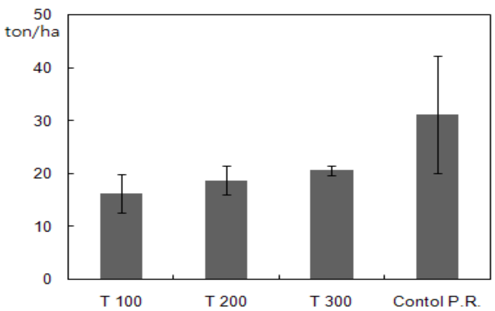

Figure 3. Fuel consumption of litter layer at thinning plots

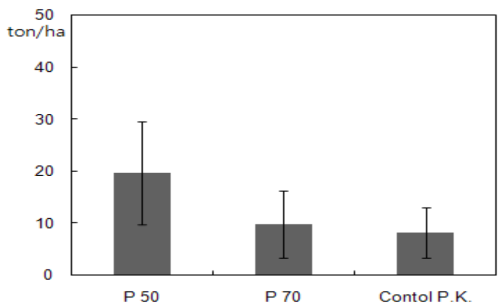

Figure 4. Fuel consumption of litter layer at pruning plots

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Scattering of tsunami wave from a forest

산림에 의한 지진해일파의 산란

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Abstract

A tsunami originated in a deep sea due to the tectonic activity such as earthquake is the transport phenomena of great scale energy, which makes much damage to sea-bounded area since its wave height becomes higher approaching the sea shore. Therefore, the tsunami wave is a kind of shallow water wave, and the characteristics similar with the shock wave in gas dynamics should be noted so remarkably that there exists a sharp discontinuity before and after the wave front. Actually there is a mathematical similarity between the equations of shallow water waves and gas dynamics. In this research, the existing code concerning the computation of unsteady shock waves is improved to simulate the propagation of tsunami waves. With this code, reflection, diffraction, and scattering of an incident shock wave are studied in the view point of physics, and the basic parameter analysis of stand density and the distance between trees is made for the application in the future.

요약

지진해일은 심해에서 지진 등의 지각 활동을 통하여 발생하는 거대 에너지의 전달 현상이며, 해안에 가까워질수록 파고가 높아져 연안 지방에 많은 피해를 준다. 따라서 지진해일파는 일종의 천수파이며, 파동 선단을 전후하여 파고의 날카로운 불연속이 존재한다는 점에서 기체역학에서 연구 대상인 충격파와 유사한 특성이 있다. 실제로 천수파에 관련된 방정식에는 기체역학 방정식과 서로 수학적 상사성이 존재한다. 본 연구에서는 기존 비정상 충격파 계산 코드를 개량하여 지진해일파의 전파를 계산할 수 있도록 하였다. 이러한

코드를 이용하여 입사하는 충격파의 반사, 회절, 산란 등의 물리 현상을 탐구하고, 임분밀도 및 수간거리 에 대한 기초 파라미터 해석을 실시하였다.

서론(Introduction)

지진해일파(일명 쓰나미)는 지진과 같은 심해 지각활동으로 발생하며, 해안선에 가까운 천해 지역에 전파되었을 경우, 갑자기 높은 파고의 파도가 몰아쳐 많은 피해를 준다. 이러한 쓰나미의 피해는 최근 일본 도호쿠 지방의 지진을 통하여 우리 사회에 많은 경각심을 주었다. 본 연구에서는 이러한 지진해일파의 방재를 위한 해안방재림의 설치 타당성에 대해 논하고자 한다. 직관적으로 살펴볼 때, 쓰나미는 파동의 일종이며, 이는 거대 에너지의 전파이므로, 일반 파동과 마찬가지로 장애물(산림)을 만났을 때 에너지의 일부를 잃어버릴 것이라 예측할 수 있다. 따라서 본 연구에서는 적절한 수학적 모델링을 통하여 지진해일파의 해안 천해지역 전파와 산림에 의한 반사, 회절, 산란 등을 다루고자 한다.

방법(Methodology)

본 연구에서는 전산유체역학(CFD: computational fluid dynamics) 기법을 사용하여 다음과 같은 가정에서 문제를 해결하고자 한다.

1) 지진해일에 의한 나무의 변형 혹은 파괴는 무시한다.
2) 수관(crown)을 제외한 줄기만을 기둥으로 모델링한다.
3) 지진해일은 불연속한 한 개의 비선형 파동으로 가정한다 (Riemann 문제).
4) 지진해일파는 국부적으로 수심이 거의 일정한 영역을 전파한다고 가정한다.
5) 유동과 산림의 마찰에 의한 감쇠는 무시한다(즉, 파동 에너지는 보존된다.).

이러한 가정 아래, 다음과 같은 방정식을 주어진 초기 조건에 대해 풀이하고자 한다.

$$\frac{\partial \mathrm{h}}{\partial \mathrm{t}} + \frac{\partial}{\partial \mathrm{x}}(\mathrm{uh}) = 0 \qquad (1)$$

$$\frac{\partial}{\partial t}(uh) + \frac{\partial}{\partial x}(u^2 h) = -\frac{\partial}{\partial x}(gh^2) \tag{2}$$

h : 파고
u : 유동 속도
g : 중력가속도(= 9.8 m/s^2)
t : 시간좌표
x : 공간좌표

식 (1), (2)는 기체역학에서 발생하는 충격파(shock wave)와 수학적 유사성(analogy)이 있다고 알려져 있다. 즉, 파고(h)를 기체 밀도(ρ)로 바꾸고, 식 (2)의 우변을 압력(p)의 구배항으로 처리한다면 기체역학에서의 연속방정식과 운동량 방정식에 해당한다. 식 (1), (2)의 시스템은 무차원화하면 다음과 같은 단일 파라미터의 영향을 받는다.

$$Fr = \frac{u}{\sqrt{gh}} \tag{3}$$

식 (3)을 Froud수 라고 하는데, 기체역학에서 Mach 수와 같은 역할을 한다. 특성 속도를 비교해 보면, 파고 3~4 미터 정도의 지진해일의 특성 속도는 음속(speed of sound)의 약 1/100 단위에 해당됨을 알 수 있다. 따라서 본 연구에서는 Fr=2.45인 경우만으로 관심 영역을 집중하기로 한다(파고비는 3.0:1).

기체역학의 Rankin-Hugonite 조건과 같이, 지진해일파에서도 적절한 좌표변환과 식 (1), (2)와 같은 보존 법칙(conservative laws)을 이용하면, 다음과 같은 관계식을 얻을 수 있다(아래첨자 1은 파동 앞, 2는 파동 뒤의 영역을 의미함):

$$\frac{h_2}{h_1} = \frac{1}{2}\left(\sqrt{1+8Fr^2} - 1\right) > 1 \tag{4}$$

$$u_2 = \left(1 - \frac{h_1}{h_2}\right) Fr \sqrt{gh_1} \tag{5}$$

따라서 식 (4), (5)를 이용하면, 주어진 파동 파라미터 Fr에 대하여 초기조건을 정할 수 있다.

결과 및 고찰(Results and Discussion)

본 문제는 계산 영역이 매우 크기 때문에 일단 가로 300미터, 세로 2.2~7미터의 계산 영역을 설정하였다. 산림이 균일하다고 가정하면, 이러한 계

산영역이 세로 방향으로 무한히 반복된다고 볼 수 있다. 따라서 계산 영역의 수간 대칭선에 대칭 영역 조건을 부여하였다(Figure 1). 2.2미터는 남해 물건리의 임분밀도(220본/ha)로부터 도출한 일반적 수간 거리이며, 7미터는 이보다 10배 임분밀도를 증가(2000본/ha)시켰을 경우의 수간 거리이다. 흉고직경은 각각 15와 30센티미터를 비교하였다(Table 1).

Table 1. Computational parameters

Simulation	Distance b/ trees (m)	Diameter of Trees (m)	Length of Forrest (m)	Reduction in Flow velocity	Reduction in Wave height
I	7	0.3	100	3.7 %	21.5 %
II	2.2	0.3	100	4.7 %	22.1 %
III	2.2	0.15	100	3.9 %	21.5 %
IV	7	0.3	150	3.1 %	21.5 %

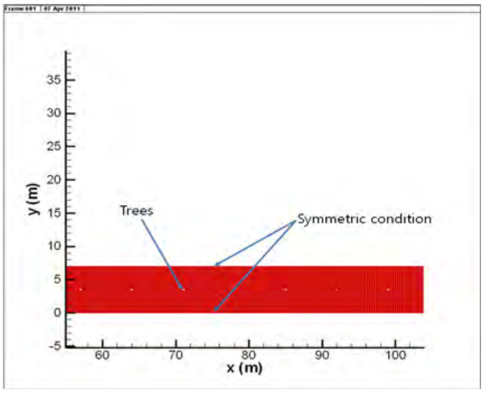

Fig. 1. Computational domain

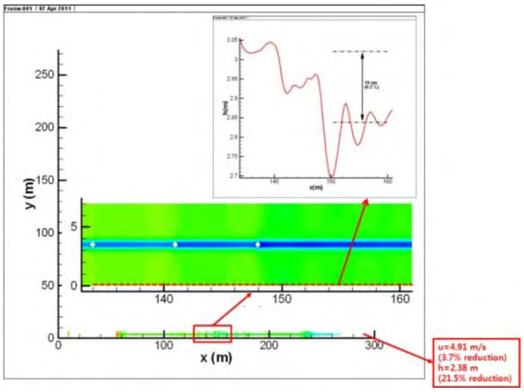

Fig. 2. Computational result (Simulation I)

지진해일파는 계산영역 좌측 40미터에서 출발하여 50미터 지점부터 시작되는 숲에 도달한다. 숲의 영역 길이는 100미터를 표준으로, 150미터까지를 계산했다. 본 연구에서의 계산은 비정상 유동에 대한 것이므로, 각 시간대별로 Figure 2와 같은 장면을 얻을 수 있다(파동 출발 38초 뒤의 모습을 확대한 것임, 격자 개수는 약 21만 개). 나무가 장애물로 작용하여 후류(wave, 그림의 파란 부분)를 형성하고 있음을 확연히 알 수 있다. Table 1.의 I번 시뮬레이션의 경우, 숲 내부의 수간 대칭선에서 후류의 파고 감쇄는 약 19센티미터(6.3%), 최종 파동 선단에서 유속에 대해서는 3.7%, 파고에 대해서는 21.5%의 감쇠 효과가 있음을 보여준다.

Table 1의 데이터를 보면 다음과 같은 잠정적인 결론을 얻을 수 있다.

1) 파고에 대한 감쇠효과는 어떤 경우에 대해서도 거의 비슷하다. 이는 시뮬레이션에서 파동의 총 에너지가 보존된다고 가정하였으므로, 파동 산란에 의해 후류에서 복원되는 지진해일파의 강도는 거의 일정하기 때문으로 보인다.
2) 유동 속도에 대한 감쇠 효과는 임분밀도가 커질수록, 즉 수간 거리가 작아질수록 크고, 나무의 흉고직경이 커지면 감쇠효과는 커진다. 그러나 숲의 영역이 넓어진다고 해서 감쇠 효과가 커지는 것은 아니었다. IV번 시뮬레이션의 경우 숲을 투과한 파동의 속도가 증가해 있는 것을 발견할 수 있었는데, 이는 빽빽한 산림이 오히려 노즐(nozzle)처럼 작용하여 유동 속도를 증가시키는 효과(벤추리 효과)를 가져왔다.

따라서 흉고직경이 큰 나무를 이용하여 임분밀도가 큰 숲을 조성한다면, 비교적 작은 면적의 숲으로도 지진 해일에 효과적으로 대응할 수 있는 해안 방재림을 조성할 수 있음을 알 수 있었다.

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Development of Algorithm for Analyzing Priority Area of Forest Fire Surveillance Using Viewshed

가시권 분석을 이용한 산불감시 우선지역 분석체계 개발

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Abstract

The algorithm for priority area of forest fire surveillance to enhance the effectiveness of fire detection was developed in this study. Viewshed analysis and fire occurrence probability maps were overlaid to decide the priority of forest fire surveillance. Viewshed was calculated with factors such as the heights of fire detection system, the heights of smoke column and the terrain roughness. Fire occurrence probability map was built using a logistic regression model. This result can be used in allocation of fire prevention resources and selection of suitable point for new fire detection system.

요약

산불감시활동에 의한 탐지확률을 높이고, 감시자원의 효율적인 이용을 위해서는 산불감시 우선지역에 대한 분석이 요구된다. 따라서 산불감시 우선지역을 추출하기 위해 가시권 분석과 산불발생확률 분석을 실시하였으며, 중첩을 통해 가중치를 부여하였다. 가시권 분석은 탐지확률과 관련된 감시자원의 높이, 산불연기높이, 지형의 굴곡도(roughness)에 따른 유효가시거리 인자를 다르게 하여 실시하였다. 산불발생확률은 로지스틱 회귀분석모형과 연료, 기상, 지형인자 및 토지피복, 접근성 인자 DB를 이용하여 분석하였다. 개발된 산불감시 우선지역 분석체계는 산불감시자원의 효율성 제고를 위한 기초자료로 활용될 수 있을 것으로 예상된다.

서론(Introduction)

우리나라의 산불은 매년 건수와 피해면적이 증가하고 있으며 이로 인한 산림생태계 피해와 진화비용 등의 사회적 비용도 증가하는 추세에 있다. 우리나라는 대부분의 산불이 입산자 실화나 논밭두렁 소각 등 인위적인 요인에 의해 발생하고 있기 때문에 산불예방활동이 우선적으로 강조되고 있다. 산불의 조기발견을 위해 각국에서는 인력과 기계화를 이용한 다양한 탐지시스템을 갖추고 있다. 우리나라는 무인감시카메라와 감시탑이 산불감시활동의 큰 비중을 차지하고 있는데, 산림청의 2006년 자료에 따르면 전국적으로 총 762대의 무인감시카메라가 설치되어 운영 중이다. 하지만 산림청의 2006년 무인감시카메라 감시실적 자료를 보면 논밭두렁 소각 등의 실적을 제외하고 직접적으로 산불을 탐지한 경우는 평균 4% 로 매우 낮게 나타나 산불감시시설의 효율성에 대한 체계적인 분석이 필요한 실정이다. 따라서 본 연구는 우리나라의 상황에 맞는 산불감시시스템 평가체계를 개발하기 위한 기초 사례연구로서 감시시설별 가시권 분석과 산불발생확률지도와의 중첩분석을 통하여 대상지역에 대한 산불감시우선지도를 생성하였다.

재료 및 방법(Methodology)

경상북도에서 3번째로 산불발생확률이 높은 봉화군를 연구대상으로 하였다. 가시권 분석은 ArcGIS Viewshed analysis를 이용하여, 가시지점의 높이(OFFSETA)는 11.6m (=감시탑 높이 10m+사람의 평균적 시선높이 1.6m)로, 대상물의 높이(OFFSETB), 즉 산불연기높이를 10m로, 유효가시거리(RADIUS2)를 25km로 설정하였다. 산불발생확률지도는 선행연구(안상현 외, 2005)를 통하여 생성하였으며, 관련인자는 임상, 고도, 경사, 산림과의 거리, 묘지와의 거리를 이용하였다. 최종 산불감시우선지도를 도출하기 위해 가시권지도와 산불발생확률지도 각각을 최소값이 0, 최대값은 1이 되도록 퍼지변환을 하였다. 산불감시우선지도는 다음 식을 이용해 산불발생확률이 높지만 가시성이 낮은 지역에 가장 높은 가중치를 주고, 반면 산불발생활률의 낮지만 가시성이 높은 지역에 가중치를 0으로 부여하였다.

[Surveillance Priority] = 0.25 * [Fire Occurrence Probability] + 0.75 * (1 - [Visibility])

결과 및 고찰(Results and Discussion)

봉화군의 가시권분석 결과, 1개 이상의 감시시설로부터 감시되는 면적은 전체의 21%로 나타났으며, 퍼지변환된 가시성의 평균값은 0.07로 매우 낮게 나타났다. 봉화군의 산불발생확률은 평균 0.57이며, 산지가 많이 분포하는 북부지역보다는 인구가 많이 분포하는 중남부 지역의 산불발생확률이 높게 나타났다(Figure 1). 최종적으로 도출된 산불감시우선도는 Figure 2와 같으며, 평균 0.8이상의 우선도를 나타내고 있다. 봉화군의 가시성이 전체적으로 매우 낮기 때문에 우선도가 높게 나타나고 있으며, 또한 산불발생확률의 패턴과 비슷하게 나타나고 있다. 추후 가중치의 변화에 대한 민감도 분석이 요구된다. 본 연구에서 개발된 산불감시 우선지역 분석체계는 산불감시자원의 효율성 제고를 위한 기초자료로 활용될 수 있을 것으로 예상된다.

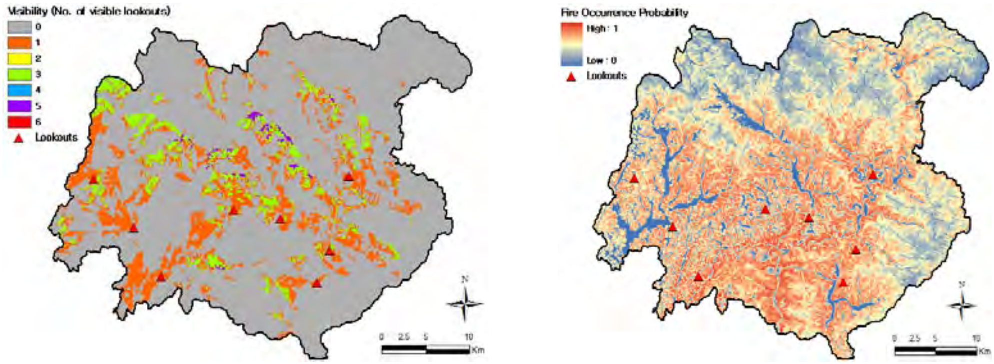

Figure 1. Visibility and Fire Occurrence Probability Map

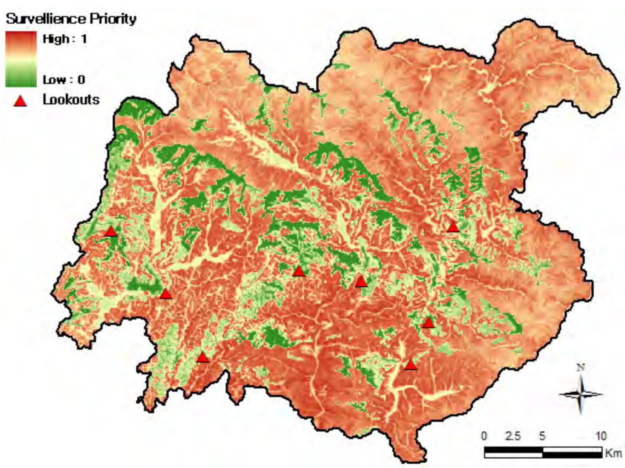

Figure 2. Surveillance Map

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Evaluating the feasibility of wood damaged by forest fire on solid biomass fuel

산불 피해목의 고형 바이오연료로 이용 가능성 평가

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Abstract

This study was performed to evaluate the feasibility of wood damaged by forest fire as solid biofuels. The degree of woods damaged by radiant heating instrument at 900 ^{o}C were classified as seriously damaged, moderately damaged and slightly damaged. As results, average values for calorific value and ash content were 4,810 kcal/kg and 0.21%, respectively. Thus, there is no difference in calorific value and ash content among the wood samples. In addition, C, H, and N contents were 50.8% (w/w), 6.6% (w/w) and 0.05% (w/w), respectively, from elemental analysis of wood samples. Therefore, these results might imply that wood damaged by forest fire has great potential feasibility of raw material for wood pellet.

요약

본 연구에서는 산불피해로부터 발생되는 피해목에 대하여 바이오매스 연료로의 이용 가능성을 평가하기 위해 국내 주요 수종인 소나무를 대상으로 실험하였으며, 산불 피해와 유사한 처리를 가한 후 연료로서의 특성을 평가하였다. 직경 28cm의 소나무 수간부위에 대하여 피해 정도 심·중·경으로 구분하여 복사열 처리를 하였다. 발열량, 함수율, 회분, 원소분석 등의 항목을 분석함으로써 산불 피해목의 바이오매스 연료 자원으로서의 특성 및 자원 이용 가능성을 평가하였다. 소나무의 전건 기준 고위발열량은 4,810kcal/kg으로 매우 우수한 것으로 분석되었으며, 회분은 0.21%로 매우 낮았으며, 탄소 함량은 50.8%, 수소는 6.6%로 분석되었다. 질소는 0.05%로 분석되어 매우 우수한 에

너지 특성을 지니고 있음을 확인하였다.

1. 서 론(Introduction)

지구온난화 및 기후변화에 따라 전 세계적으로 산림재해가 증가하고 있다. 특히 2000년과 2002년 국내 동해안에서 발생한 대형산불 등 국내에서도 산불피해지로부터 발생되는 산불 피해목의 목재로서의 이용 가능성에 대한 접근이 시도되고 있다. 국립산림과학원에서 1997년부터 2006년에 걸쳐 산불 피해목에 대한 재질변화 연구를 통해 과학적인 자료를 구축한 바 있다. 본 연구에서는 산불 피해목의 바이오에너지 이용 가능성을 평가하기 위해 산불 피해 정도에 따른 시료를 제조하고, 발열량, 회분 및 주요 원소(C, H, N 등)에 대한 에너지 관련 특성을 측정하고 결과를 비교하였다.

2. 재료 및 방법(Methodology)

2.1 공시재료

직경 28cm, 길이 1.2m의 소나무(*Pinus densiflora*)를 이용하여 30cm 길이로 3등분하여 공시재료를 제조하였다. 시료의 산불피해를 묘사하기 위해 피해도에 따라 심, 중, 경으로 구분하였다. 심은 수피를 포함하여 변재 1cm 내부까지 연소, 중은 수피 전체 연소, 경은 수피 두께의 1/2연소를 가정하여 시료를 제조하였다.

Table 1. Sample classification.

Sample No.	Damage	Damage range	Diameter (cm)	Thickness of bark (cm)
1	Seriously	Bark and 1cm-thick of sapwood	28.3	0.74
2	Moderately	Bark	28.3	0.74
3	Slightly	Half thickness of bark	28.0	0.78

2.2 산불피해에 따른 시료 제조

산불 피해는 Table 1에서 제시한 방법 분류에 따라 국립산림과학원에서 보유하고 있는 착화성 시험기를 이용하여 처리하였다. 간단하게 설명하면, 900℃의 복사열을 시료 표면에 처리하여 피해도에 따라 연소 정도를 가감하여 수행하였다.

Figure 2. Prepared sample.

2.3 결과 분석

준비된 시료는 국립산림과학원 고시 제2009-2호(목재펠릿 품질규격)에서 제시하고 있는 시험방법에 따라 함수율, 회분, 발열량을 분석하였으며, 국립산림과학원 보유 원소분석기(EA1112A, Thermo, USA)를 이용하여 원소분석을 수행하였다.

3. 결과 및 고찰(Results and Discussion)

3.1 연소정도에 따른 시료의 표면변화

연소 정도에 따라 표면에 수피에 생성된 정도를 구분하는 것은 쉽지 않은 것으로 판단되었다(Figure 3. Lower line). 이는 산불에 의한 수목에 피해가 발생해도 목부의 대부분에는 영향을 미치지 않기 때문으로 판단된다.


Figure 3. Samples from heat radiation treatment.
(from left; seriously, moderately, slightly. Upper line: cross, Lower line: longitudinal)

3.2 함수율, 발열량, 회분분석 결과

산불피해처리를 통해 제조된 시료의 중간부위에서 3cm 두께의 함수율은 감소하였으며, 처리 정도에 따라 함수율에 차이가 발생하는 것을 확인할 수 있다. 실험 조건에서 산불 피해 처리를 위한 시료는 길이가 30cm로 비교적 짧기 때문에 처리 시간이 지속됨에 따라 함수율 제거 효과가 있었던 것으로 판단된다. 반면, 발열량이나 회분에서는 시료의 처리 조건에 따른 차이를 확인할 수 없었다. 발열량은 매우 우수하여 목재펠릿으로서의 이용 가능성이 높은 것으로 사료된다.

Table 2. The comparison of moisture content, calorific value and ash content.

Sample No.	Moisture (%)	Calorific value (kcal/kg)	Ash (%)
1	17.6	4,780	0.20
2	32.2	4,810	0.19
3	39.1	4,860	0.22

3.3 원소분석 결과

Table 3.에서 제시된 원소분석 결과에서는 에너지 이용을 위한 주요 원소 함량에 차이가 없는 것으로 사료된다.

Table 3. The results of C, H, N elemetal analysis

Sample No.	C(%)	H(%)	N(%)
1	50.35	6.52	0.05
2	50.82	6.60	0.05
3	51.29	6.67	0.08

4. 참고문헌(References)

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Chemical properties of a Soap-based Class A Foam for Wildfire

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Abstract

Our group has developed an environmentally friendly Class A foam for wildfire. We used eco-friendly, naturally derived soap and a highly biodegradable chelating agent to create samples that were evaluated for foaming, foam stability, and low-temperature stability. These chemical properties are dependent on the chelating agent and the component of fatty acid potassium (potassium oleate, potassium laurate), from which the soap is composed. We found that the foaming and foaming stability were equal or greater than the generally utilized EDTA, even when a highly biodegradable chelating agent was used. We also discovered an optimum fatty acid composition that demonstrates significant foaming and foaming stability, as well as a fatty acid composition that displays significant low-temperature stability. Therefore, we demonstrated that selecting the optimum chelating agent and fatty acid composition makes it possible to develop a firefighting foam for wildfires that has low environmental impact.

Introduction

In 2007, our group (Kitakyushu City Fire and Disaster Management Bureau, University of Kitakyushu, etc.) successfully developed and began marketing a Class A foam for structural fire (Mizuki et al., 2007; Mizuki et al., 2010). That foam is characterized by 2 factors, a low toxicity to aquatic life and high biodegradability. The key to this special firefighting foam, which has a low impact on the environment, is soap. This is because soap instantly reacts to minerals (Ca^{2+}, Mg^{2+}, etc.) that exist in the natural environment to become harmless metallic soap. It loses its interfacial activity and immediately loses toxicity.

Another reason for soap's low environmental impact is the fact that it is broken down in a matter of days, and thus has a very high degree of biodegradability.

Our next step was to begin developing a Class A foam for wildfire based on the Class A foam for structural firefighting we developed using soap. Agents used to extinguish wildfires significantly affect the environment since a large volume of extinguishing agent is dispersed over the natural environment. For that reason, it is desirable for extinguishing agents used in forest fires to have a low toxicity to aquatic creatures and a high degree of biodegradability. Consequently, soap is believed to be most suitable as the principle component for firefighting foam.

Although soap has low toxicity and is highly biodegradable, the metallic soap produced through soap's specific reaction inhibits the production and retention of foam. As a result, the foaming and foam stability, which are important to firefighting foam, are reduced. Thus, preventing the production of metallic soap is key to stopping the reduced performance of firefighting foam. The most effective way to prevent the production of metallic soap is the use of a chelating agent. The commonly used chelating agent, EDTA comes to mind, but it has poor biodegradability and there are concerns over its environmental impact. Therefore, we searched for a chelating agent that is highly biodegradable and has a low environmental impact.

In addition, soap and highly biodegradable chelating agents have an extremely strong mutual interaction and gel even at low concentration. It was presumed that low-temperature stability would deteriorate because of this specific gel-forming reaction.

In light of this, our group researched the impact of the foaming properties and foam stability of firefighting foam that uses environmentally friendly, highly biodegradable chelating agents. Foaming properties and foam stability were assessed using expansion ratio and rate of reduction, which are testing standards for Class A firefighting foam in Japan. The pour point was used to assess low-temperature stability when a highly biodegradable chelating agent is utilized. Since we also believed that the foaming properties, foam stability, and low-temperature stability are impacted by the fatty acid potassium component that comprises the soap, we worked to develop a Class A foam for wildfire by optimizing the fatty acid composition.

Experimental

Materials

A sample was created that mixed 40% soap components (potassium laurate, potassium oleate, diluent), 40% chelating agent, and 20% diluent. We used 5 types of chelating agent: Ethylendiaminetetraacetic acid (EDTA), L-glutamate diacetate (GLDA), L-asparticaciddiacetic acid (ASDA), Methylglycineacetic acid (MGDA), and [S,S]-ethylediaminedisuccinic acid (EDDS).

Foaming test

The foaming were assessed using expansion ratio conforming to Japan's testing standards for Class A firefighting foam. 40mL of the firefighting foam was diluted in 4L of tap water set to 20℃ and poured into a fire extinguisher. Nitrogen gas was injected at 0.85MPa. After 10min., the foam mixture was placed in a foam-collection container. Its height was measured and the expansion ratio was found using the following equation:

Expansion ratio = (foam height[m]) x (cross section of foam-collection container [m^2]) / (aqueous fire-extinguishing solution volume[m^3])

Foam stability test

Foam stability was assessed using rate of reduction conforming to Japan's testing standards for Class A firefighting foam. The foam stability test measured the time it took 25% (1L) of the foam produced to return to an aqueous solution.

Low-temperature stability test

A 45ml sample was placed in a test tube to measure the pour point, and cooled using an ethanol bath maintained at -40℃ to -50℃. The test tube was removed each time the temperature dropped 2.5℃ and carefully tilted to confirm whether the sample surface was fluid. If fluidity was not seen even when the test tube was held horizontally for 5sec., the pour point was established at that temperature + 2.5℃.

Results and Discussion

ASDA, MGDA, GLDA, and EDDS are chelating agents believed to have a favorable degree of biodegradability. Both the expansion ratio and rate of reduction were shown to be high for ASDA, MGDA, EDTA, and GLDA, in that order. Therefore, even chelating agents with good biodegradability perform equally or better than the commonly used EDTA.

Next, we optimized the composition of potassium oleate and potassium laurate. For EDTA, various fatty acid compositions maintained a high expansion ratio and rate of reduction, but ASDA, MGDA, and GLDA had both a high expansion ratio and rate of reduction when potassium oleate was around 60%. Even among highly biodegradable chelating agents, both the expansion ratio and rate of reduction were high for ASDA and MGDA, and an optimum ratio between potassium laurate and potassium oleate was demonstrated.

MGDA and GLDA, chelating agents with typically good biodegradability, were used for the pour point. The ratio of fatty acids was altered to research the optimum composition of potassium oleate and potassium laurate. For either chelating agent, when the ratio of potassium oleate was increased, the pour point was lowered. The pour point was at its lowest when the ratio of potassium oleate was 60%. Moreover, the pour point rose as the ratio of potassium oleate was increased, leading to the discovery that a 60:40 ratio between potassium oleate and potassium laurate had the highest fluidity.

Based on the above, by selecting the chelating agent with the best biodegradability and the fatty acid composition, we were able to develop a Class A foam for wildfire that has high foaming and foam stability, plus a high degree of low-temperature stability.

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Effectiveness of Rehabilitation Treatments for Forest Restoration in Post-wildfire Area: A Case on a Hillside slope in Eastern Coastal Forest Area, Republic of Korea

산불피해지 산림복원을 위한 사면복구처리 효과 분석 - 동해안 산불피해사면을 대상으로 -

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Abstract

In the spring of 2000, a large-scale wildfire burned the biggest mountain range in the eastern coastal area in Republic of Korea. Although various rehabilitation treatments were often applied to minimize surface erosion and restore vegetation cover after the wildfire, few studies have quantified their effectiveness. The aim of our study was to evaluate effectiveness of rehabilitation treatments, and discuss considerations on their applications in post-wildfire areas. We based vegetation coverage, rainfall intensity (regulating surface erosion) and sediment yield data from 7 rehabilitation treatments (direct seeding, hydroseeding, tree planting, terrace-sodding, stone masonry, vegetation sack and burned-log barrier) compared to untreated field data. We found that our post-wildfire area with the lack of a sprouting source (caused by high wildfire severity, eroded sandy soil and steep slope) needed to allow approximately four years or more for physical stability throughout natural recovery of native vegetation. In general, wildfires destroy plant community and create a subsurface water-repellent layer, and thus rainfall interception by vegetation and litter layer is reduced and soil infiltration is restricted, thereby increasing overland flow and sediment yield. Although vary, the restoration time period, however, was reduced by application of the rehabilitation treatments. Our findings suggest considerations of the vegetation conditions, slope and location of treatment sites and the potential

structure problem of treatments, and this should be important for forest restoration in post-wildfire areas.

요약

한국 동해안지역은 2000 년 봄 대규모 산불로 인해 많은 산림이 소실되었다. 이러한 산불피해지역 토양침식의 최소화와 복구를 위한 다양한 사면처리가 이루어지고 있으나, 그 효과에 대해 명확한 구명이 이루어지지 않고 있다. 본 연구에서는 산불피해지에 다양한 사면처리공법을 적용하여 그 효과분석 및 고찰을 실시하였다. 총 7가지의 사면처리공법(파종, 종자뿜어붙이기, 일반조림, 선떼붙이기, 산돌쌓기, 녹색마대공, 불탄나무편책공)으로 처리한 사면과 대조구에 대한 토사유출량, 강우량, 강우강도, 식생피도 등을 분석하였다. 그 결과 높은 피해강도, 토양침식, 급경사 등 악조건의 사면은 자연복원력을 회복하는데 약 4년 혹은 그 이상의 시간이 필요한 것으로 나타났다. 일반적으로 산불은 지표식물을 파괴하고 강우침투를 억제함으로써 지표수를 증가시키고 토양침식을 증가시킨다. 하지만 사면처리공법의 적용기간 동안 토양침식은 명확히 줄어드는 것으로 나타났다. 또한 산불피해지 복구를 위해서는 지피식생의 상태, 사면경사, 사면처리의 물리적 구조 등이 충분히 고려되어야 할 것으로 판단되었다.

Introduction

Worldwide, numerous studies have been conducted on rehabilitation treatments, such as grass seeding (Pinaya et al. 2000; Robichaud et al. 2006), log barriers (Raftoyannis and Spanos 2005; Wagenbrenner et al. 2006), wood chips (Buchanan et al. 2002; Kim et al. 2008), mulching (Dodson and Peterson 2010) and fertilizers (DeBano 1989). Based on the results in these studies, there is no doubt that these rehabilitation treatments in post-wildfire areas can be important in minimizing the risk of flooding and sedimentation. However in Republic of Korea, most of previous studies (e.g., Chun et al. 2003; Lee et al. 2004) have concentrated on initial (or short-term) changes of physical, chemical and ecological characteristics caused by wildfires compared to unburned areas, and few studies have quantified effectiveness of various rehabilitation treatments based on field investigations of vegetation recovery and sediment production in post-wildfire areas. The main aim of this study was to evaluate the effectiveness of rehabilitation treatments for surface erosion control and vegetation recovery after a severe wildfire in the eastern coast area, Republic of Korea. The specific objectives were to: (i) evaluate effectiveness of various rehabilitation treatments on vegetation recovery and surface stability, and (ii) discuss considerations on their applications for forest restoration in post-wildfire areas. In this study, we applied 7 rehabilitation treatments, which are currently used in burned forest areas in Republic of Korea.

Methodology

This study was conducted on the hillside slope in Mount Geombong (681.6 m), which is located in the Nogock, Wondeock, Samcheock, Gangwondo, Republic of Korea (Figure 1). The hillside slope is underlain primarily by not only sedimentary rocks but also metamorphic rocks of Cretaceous age, and its surface is mainly covered by eroded sandy soil (Seo et al. 2010). Of all plots settled, the 7 plots, except for 1 untreated control plot, were established by rehabilitation treatments, which are commonly performed to restore post-wildfire area in Republic of Korea. These are (i) direct seeding, (ii) hydroseeding, (iii) tree planting, (iv) terrace-sodding, (v) stone masonry, (vi) vegetation sack and (vii) burned-log barrier. These rehabilitation treatments were conducted after cutting of burned trees within plot boundaries, while the burned trees in the untreated control plot were remained (Figure 2a). In this study, we investigated daily rainfall data collected at the Imwon Meteorological Observatory closet to study site, which is released on website (www.e-bangjae.com/samcheok/) of Samchoek Emergency Management Agency. From this dataset, we used all rainfall data during investigation period (i.e., from June to October for 5 years (2002–2006)) to confirm effects of rainfall intensity on variation in surface erosion in post-wildfire area. To estimate sediment yield caused by surface erosion in post-wildfire areas, we collected sediments that were trapped by catchment barrels at the bottom of 8 plots. Here to avoid overestimation of sediments which can be caused by constructions of rehabilitation treatments, we excluded the data collected at the first time in 2002 from the dataset. Finally, the sediment biomass data of all plots were expressed as a sediment yield per unit plot area (SY, g/m^2). To reveal the explanatory parameters that were most influential to surface erosion in this study, we used a generalized linear model (GLM) with a Gaussian error distribution and identity link function. The responsible variable was SYs in each elapsed-year of each rehabilitation treatment plot. The explanatory variable chosen to explain the SYs was the rainfall parameter expressed by the cumulated daily rainfall greater than or equal to *x* mm (DRc≥*a*MM). Here, the *a* value was varied from 0 mm (annual rainfall) to 150 mm at 10-mm intervals (i.e., 0, 10, 20, … , 130, 140 and 150 mm). Model selection was performed by the best-subset procedure based on

Akaike's Information Criterion (AIC), and the regression model(s) with the AIC value ranging from the smallest value (x) to x+2 was considered the best-fit model for the measured variation in the data (Burnham and Anderson 2002). Two-factor repeated measures analysis of variance (RM ANOVA) was used to evaluate significant differences in SYs according to the rehabilitation treatments and the elapsed-years, with multiple sampling times in each plot as the repeated factor. Here based on the result in previous analysis, all SY data were expressed as a SY per unit rainfall (unit SY, $g/m^2/mm$) after division by the DRc≥aMM selected in each plot. When the effects of the rehabilitation treatments and the elapsed-years on unit SY were significantly different on the two-factor RM ANOVA, Tukey-HSD multiple comparison was performed. Here $P < 0.05$ was considered to indicate statistical significance for all tests. The normality of the distributions was tested using the Kolmogorov–Smirnov test. All statistical analyses were performed using the statistical language *R* version 2.11.1. (http://www.r-project.org).

Results and Discussion

Model selection using AIC in the GLM revealed that rainfall intensities of the best-fit models explaining variations in SYs in all plots increased generally along the spectrum of elapsed-year but their increasing trends were slightly different according to rehabilitation treatments (Table 1). In the untreated control plot, DRc≥10MM was the best predictor explaining SY in the 1st investigated-year, and models of DRc≥0MM and DRc≥20MM were similarly influential; DRc≥20MM was the best predictors explaining SY as well as DRc≥10MM in the 2nd investigated-year; DRc≥20MM was the best predictor explaining SY in the 3rd investigated-year; DRc≥40MM was the best predictor explaining SY, followed by DRc≥30MM in the 4th investigated-year; and DRc≥40MM was the best predictor explaining SY in the 5th investigated-year and model of DRc≥50MM was equally well supported. The best-fit models selected in the direct seeding plot and the tree planting plot had very similar trends with the untreated control plot, except for in the 3rd investigated-year that models of DRc≥30MM and/or DRc≥40MM were selected. In the plots of the terrace-sodding and the stone masonry, models that have relatively higher rainfall intensities compared to the untreated control plot were selected in the 1st, 2nd and 3rd investigated-year but similar models with those in the untreated control plot were selected in the 4th and 5th investigated-year. However, the best fit models explaining SYs in the plots of the hydroseeding, the vegetation sack and the burned-log barrier generally showed higher rainfall intensities than those in the untreated control plot all over the investigated-year. Especially, in the 3rd investigated-year, the models of DRc≥50MM and/or DRc≥60MM with high rainfall intensities were already selected as influential predictors explaining SY in these plots. The result of two-factor RM ANOVA showed that annual mean values in unit SYs in all plots decreased generally along the spectrum of elapsed-year; the unit SYs are relatively larger in order of the 1st, 2nd, 3rd, 4th and 5th investigated-years, although this trend has partially non-significant differences (Table 2). The unit SYs, however, were quite differed as a function of rehabilitation treatment. Especially in the 1st investigated-year, whereas the unit SYs in the untreated control plot and the direct seeding plot were greater than or similar with 1.0 g/m^2/mm, the units SYs in the plots of the hydroseeding, the tree planting, the vegetation sack and the burned-log barrier were less than 0.5 g/m^2/mm. These differences according to the rehabilitation treatments were reduced with the passing of year, and the unit SYs in all plots, except for the untreated control plot (approximately 0.11 g/m^2/mm), were less than 0.1 g/m^2/mm in the 3rd investigated-year. The unit SYs in all plots were further reduced and finally reached below 0.03 g/m^2/mm in the 5th investigated-year, although not significantly different from the 3rd investigated-year to the 5th investigated-year.

Table 1. The models selected in GLM for rainfall intensity controlling surface erosion according to rehabilitation treatment and elapsed-year.

	Structure of the model selected in GLM									
	1st year		2nd year		3rd year		4th year		5th year	
	Model	ΔAIC	Model	ΔAIC	Model	ΔAIC	Model	ΔAIC	Model	ΔAIC
ntreated control	~ DRc≥10MM	–	~ DRc≥20MM	–	~ DRc≥20MM	–	~ DRc≥40MM	–	~ DRc≥40MM	–
	~ DRc≥0MM	0.5	~ DRc≥10MM	1.1			~ DRc≥30MM	1.3	~ DRc≥50MM	–
	~ DRc≥20MM	1.1								
irect seeding	~ DRc≥10MM	–	~ DRc≥10MM	–	~ DRc≥30MM	–	~ DRc≥40MM	–	~ DRc≥40MM	–
	~ DRc≥20MM	0.9	~ DRc≥20MM	0.4					~ DRc≥50MM	–
	~ DRc≥0MM	1.3								
ydroseeding	~ DRc≥30MM	–	~ DRc≥30MM	–	~ DRc≥50MM	–	~ DRc≥50MM	–	~ DRc≥60MM	–
					~ DRc≥40MM	1.2	~ DRc≥60MM	0.9	~ DRc≥70MM	–
							~ DRc≥70MM	0.9		
ee planting	~ DRc≥20MM	–	~ DRc≥20MM	–	~ DRc≥40MM	–	~ DRc≥40MM	–	~ DRc≥40MM	–
	~ DRc≥10MM	0.3			~ DRc≥30MM	0.5			~ DRc≥50MM	–
errace-sodding	~ DRc≥20MM	–	~ DRc≥30MM	–	~ DRc≥30MM	–	~ DRc≥40MM	–	~ DRc≥40MM	–
	~ DRc≥30MM	1.6							~ DRc≥50MM	–
one masonry	~ DRc≥20MM	–	~ DRc≥30MM	–	~ DRc≥30MM	–	~ DRc≥40MM	–	~ DRc≥40MM	–
					~ DRc≥40MM	0.9	~ DRc≥50MM	1.2	~ DRc≥50MM	–
									~ DRc≥30MM	0.9
egetation sack	~ DRc≥20MM	–	~ DRc≥40MM	–	~ DRc≥50MM	–	~ DRc≥50MM	–	~ DRc≥60MM	–
	~ DRc≥30MM	0.6			~ DRc≥60MM	1.4	~ DRc≥60MM	0.2	~ DRc≥70MM	–
							~ DRc≥70MM	0.2		
urned-log barrier	~ DRc≥30MM	–	~ DRc≥40MM	–	~ DRc≥60MM	–	~ DRc≥60MM	–	~ DRc≥60MM	–
			~ DRc≥50MM	1.8			~ DRc≥70MM	–	~ DRc≥70MM	–

Note: The responsible variable (y) is the sediment yield (SY, g/m2) and the explanatory variables are the rainfall parameters expressed by the cumulated daily rainfall greater than or equal to x mm (DRc≥aMM, mm). The regression model(s) with the AIC value ranging from the smallest value (x) to x+2 was considered the best fit model (Burnham and Anderson 2002)

Table 2. Differences in sediment yield per unit rainfall according to rehabilitation treatment and elapsed-year.

	Sediment yield per unit rainfall ($\times 10^{-1}$) (Unit SY, g/m^2/mm)				
	1st year	2nd year	3rd year	4th year	5th year
Untreated control	12.24 ± 4.67 a	5.36 ± 1.04 abcd	1.06 ± 0.15 cd	1.12 ± 0.39 cd	0.27 ± 0.17 cd
Direct seeding	9.71 ± 2.87 ab	3.06 ± 0.79 bcd	0.80 ± 0.15 cd	0.83 ± 0.28 cd	0.25 ± 0.15 cd
Hydroseeding	3.95 ± 1.23 bcd	0.69 ± 0.15 cd	0.42 ± 0.11 cd	0.11 ± 0.04 cd	0.09 ± 0.05 d
Tree planting	4.90 ± 1.62 bcd	2.34 ± 0.77 bcd	0.50 ± 0.12 cd	0.92 ± 0.44 cd	0.10 ± 0.05 d
Terrace-sodding	6.03 ± 1.78 abcd	5.73 ± 1.24 abcd	0.56 ± 0.12 cd	0.87 ± 0.23 cd	0.29 ± 0.15 cd
Stone masonry	7.66 ± 3.26 abc	3.34 ± 0.85 bcd	0.81 ± 0.18 cd	0.62 ± 0.17 cd	0.25 ± 0.10 cd
Vegetation sack	2.45 ± 0.67 cd	1.26 ± 0.37 cd	0.44 ± 0.13 cd	0.61 ± 0.21 cd	0.12 ± 0.06 d
Burned-log barrier	0.78 ± 0.21 cd	0.77 ± 0.24 cd	0.30 ± 0.14 cd	0.17 ± 0.08 cd	0.05 ± 0.02 d

An application of rehabilitation treatments should lead to increasing vegetation recovery and subsequent surface stability for forest restoration in post-wildfire areas. This is particularly important to understand an effect of wildfires in regulating not only the existence and maintenance of stream-dwelling organisms but also the transfer and residence time of sediment for aquatic habitat formation. Moreover, our findings also provide important information to establish watershed management strategies when considering disaster prevention in densely populated areas. However, there are many knowledge gaps in understanding effectiveness of post-wildfire rehabilitation treatments at the watershed scale. For example, this study does not cover a range of various forests (species, seral stage, growth rate, artificial versus natural, harvested versus non-harvested) and/or geological conditions in the source watersheds. Hence, effectiveness of various rehabilitation treatments discussed in this study may not be available to various watersheds having different natural conditions. Furthermore, the chronological sequence from recruitment to fluvial export of sediment in post-wildfire areas was not fully examined. The sediment recruited into small streams in post-wildfire areas are fluvially exported to downstream rivers, repeating the cycle of transport and storage, and thus a time lag between initial recruitment (in small streams adjacent to post-wildfire areas) and fluvial export (in downstream rivers) should vary according to an application of rehabilitation treatments. The role of the rehabilitation treatments on the chronological sequence of sediment produced in post-wildfire areas is absolutely necessary to establish sediment budgets considering various geomorphic disturbances at the watershed scale.

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Introduction and growth of *Pinus densiflora* at the naturally regenerated forest stands after forest fire

산불피해지 내 천연갱신림에서 소나무의 이입과 생장

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Abstract

Sixteen years after the onset of natural regeneration on the burned area at Goseong, Quercus spp. are dominant at the mountain slope and valley while the *Pinus densiflora* showed an tendency to inhabit the mountain ridge and rocky land. The purpose of this research is to investigate the influence of a forest fire by examining the number of *Pinus densiflora* introduced and the growth of it according to the various intensity and frequency of fire. Thus, this research surveyed the number of the introduced pines and annual growth. The research result revealed that most *Pinus densiflora* were established between 1995 and 1999 on the area which was burned once in 1996. On the other hand, most *Pinus densiflora* were introcuced between 2005 and 2009 on the area which was bured twice in 1996 and 2000. There has been more differentiation in tree height at one-time damaged area than two-time damaged area. The annual growth of *Pinus densiflora* increased sharply between 3 to 8 years after establishment, and stabilized from 9 to 11 years after establishment.

요약

강원도 고성 산불피해지를 자연복원시켜 16년이 경과한 현재 사면부와 계곡부는 참나무류가 우점하는 반면 능선부 및 암석지에서는 소나무가 서식하는 양상을 보였다. 본 연구에서는 산불의 강도와 횟수가 다른 지역의 소나무 이입과 생장을 조사하여 산불의 영향을 알아보고자 하였다. 각 조사지에서 소나무의 이입된 개체수, 수령에 따른 수고, 연년수고 생장량을 조사하였다. 그 결과 1회 피해지에서는 1995-1999년에, 2회 피해지에서는 2005-2009년에 가장 많은 개체가 유입되었으며 1회 피해지는 2회 피해지에 비해 수고의 분화가 많

이 일어났다. 소나무의 연년수고 생장량은 발생 3-8년에는 급격히 증가하며 8-11년에는 유지되는 경향을 보였다. 향후 숲의 발달에 관한 지속적인 연구가 필요할 것으로 생각된다.

서론(Introduction)

강원도 고성은 1996년과 2000년 산불피해를 받으면서 사면부와 계곡부에서 우점 수종인 소나무를 맹아생장력이 강한 참나무류가 대체하는 양상을 보이고 있다. 반면, 능선부와 암석지처럼 토양이 척박하여 활엽수의 생장이 어려운 곳에서는 소나무 실생묘가 도입되고 있다(임과 안 2011). 산불은 식생에 물리적 피해를 입힐 뿐 아니라 주변 환경을 변화시켜 식생의 개체군 이입과 생장에 영향을 미칠 것으로 사료된다. 본 연구는 산불피해지 내 천연갱신림에서 산불이 소나무 이입과 생장에 미치는 영향을 알아보기 위해 수행되었다.

재료 및 방법(Methodology)

조사지역은 강원도 고성군 죽왕면 산림청 시험림 내 자연복원지의 능선부 5곳이다. 각 조사지에 능선을 따라 50m(조사구 5는 40m)를 설정하고 이를 중심으로 양쪽으로 10m씩을 조사구로 설정하였다. 조사구 1, 2, 3, 4(2회 피해지)는 1996년과 2000년 산불로 전소된 지역이며 조사구 5(1회 피해지)는 1996년 지표화 피해를 입은 지역이다. 조사구 내의 소나무 위치, 수령, 마디길이, 결실여부 등을 조사하였다. 또한 이를 바탕으로 각 조사지에서 1995년부터 2009년까지 15년간 이입된 소나무 개체수를 5년 단위로 분석하였으며 소나무 수령에 따른 수고를 능선별로 비교하였다. 마지막으로 다섯 곳의 조사구에서 발견된 모든 소나무 개체의 연차별 연년수고 생장량을 조사하였다.

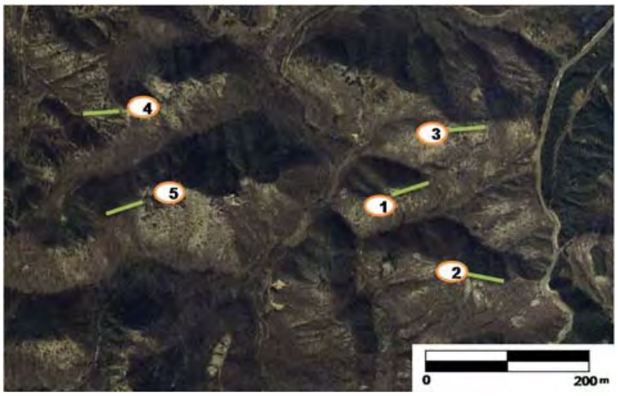

Fig. 1. 조사구의 위성영상 사진

결과 및 고찰(Results and Discussion)

각 조사구의 1996년부터 2009년 사이에 이입된 소나무 개체수를 5년 단위로 분석한 결과 조사구 5는 1996년 산불을 전후로 개체 이입이 가장 많으며 이후 감소하였다. 반면 조사구 1, 3, 4는 2005년에서 2009년 사이에 이입된 개체가 가장 많았다. 이와 달리 조사구 2는 2005-2009년 사이에 개체 이입이 없는데 이것은 조사구 내의 참나무와의 경쟁으로 인한 것으로 사료된다.

수령별 수고가 가장 큰 곳은 조사구 4였으며 조사구 2는 수고생장이 저하된 양상을 보였다. 조사구 4의 능선부 주변은 참나무류 밀도가 높지 않은 반면 조사구 2의 능선부 주변은 높은 참나무류 밀도를 보여 경쟁으로 인한 수고 생장의 차이인 것으로 보인다. 조사구 5는 다른 조사구와는 달리 수령이 많은 개체의 비율이 높고 수령에 따른 수고의 분화가 많이 일어난 것으로 나타났다.

소나무의 연차별 연년수고 생장량을 조사한 결과 발생 1-3년까지는 정체되어 있으나 3년부터 8년까지는 연간수고 생장량이 8.6cm에서 22.2cm로 매년 가파르게 증가하였다. 이후 8년부터 11년까지는 거의 변화가 없었으나 12년부터는 대폭 증감하는 양상을 보인다. 12년 이후의 연년수고 생장량은 조사구 5의 특징을 반영하는 것으로 사료된다. 수령이 12-16년 사이인 개체는 총 62개체로 그 중 조사구 1-4에 해당되는 것은 13%에 해당하는 8개체 뿐이기 때문이다.

국내에서 산불로 인해 숲이 전소된 지역인 강원도는 소나무림이 전소된 이후 참나무림으로 갱신되고 있으며 소나무는 참나무가 서식하기에 어려운 척박한 능선부 및 암석지를 중심으로 분포하고 있다. 향후 숲의 발달은 참나무와 소나무의 경쟁에 의해 결정될 것으로 사료되나 이와 관련된 연구는 거의 진행되지 않고 있는 실정이다. 척박한 토양환경과 건조한 기후의 강원도(임 2000)에서 참나무가 수세를 유지할지, 소나무가 다시 우점 식생이 될 지 지속적인 연구가 필요할 것으로 판단된다.

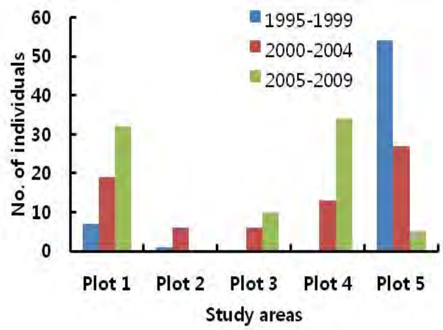

Fig. 2. 각 조사구의 5년간 유입개체수

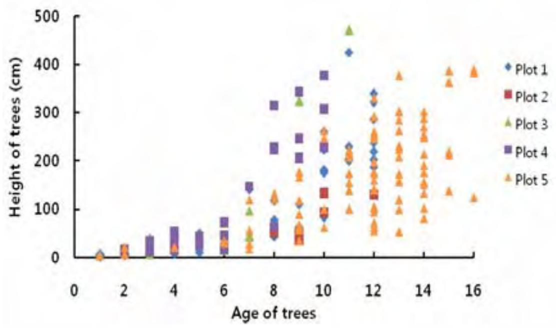

Fig. 3. 각 조사구의 소나무 수령에 따른 수고

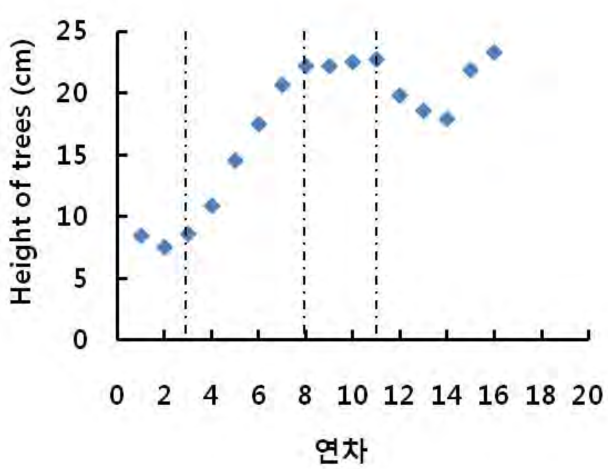

Fig. 4. 소나무의 연차별 연년수고 생장량

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Policy of Forest Fire Prevention and Analysis of Forest Fire during Chosun Dynasty

조선시대 산불방지정책 및 산불현황

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Abstract

This study surveyed historical records on outbreak and features of forest fires during Chosun Dynasty's 518 years in being and analyzed the Annals of the Chosun dynasty; The Diaries of the Royal Secretariat, archives from Records of the Border Defense Council, The Compilation of Ministry Proposals, Posthumous Records of King Cholchong etc. Forest fires were most prevalent and extreme during King Hyunjong(14 cases) and King Sunjo(13 cases) due to strong wind, and the biggest-ever forest fire broke out in the fourth year of King Soonjo(1804) in the east coast of Korea in Kangwon province. The fire had resulted in 61 fatalities and 2,600 destroyed houses. Forest fire in the east coast of Korea, Kangwon province, in the 13th year of King Hyeonjong(1672) is recorded to have caused the highest number of deaths, 65people. The most frequent cause of forest fires during Chosun Dynasty was unidentified(42 cases), followed by accidental fire(10 cases), arson or lightning(3 cases), fire during hunting(2 cases), play with fire by children, destruction of patty fields and dry fields by fire and house fire (1 case respectively). By region, 56% of forest fires erupted in the east coast(39 cases) and this was followed by the west sea(9 cases), Seoul and central region(8 cases) and the southern part of Korea(7 cases). By season, spring was found to be most vulnerable to forest fire as it accounted for 73% of the total amounting to 46 cases. Behind were summer(11 cases), winter(6 cases) and autumn(0 case). Specifically, most forest fire broke out on April and May, which is the same as today. Archives and literature indicate that the person who involved in forest fire by accidental as well as arson had to be punished by banishment, expulsion from government office and public hanging. Also, officials in charge of the region that suffered forest fire were subject to reprimand. In conclusion, risk and gravity of forest fires were evident during the Chosun Dynasty as specified in historical archives and share many similarities with today's forest fires in terms of the duration and regional patterns.

요약

본 연구는 역사기록서 분석을 통한 조선왕조시대 518년 동안의 산불발생 및 특성, 그리고 정책에 관한 기록을 고찰하였다. 본연구에 활용된 연사기록서는 조선오앙조실록, 승정원일기, 국역비변사등록, 각부청의서존안, 철종행장 등으로 조선시대 왕조별로 산불이 기록된 문헌을 조사, 분석하였다, 역사기록문헌에서 기록된 산불내용은 발생개요, 산불종류, 산불피해 등에 관한 사항과 함께 송전의 산불예방조치사항 등이 포함되어 있다. 조선왕조 역사기록서를 분석한 결과, 산불발생건수가 많았던 왕조는 현종(14건)과 순조(13건)로 강풍으로 인한 산불피해가 극심한 것으로 기록되었고 최대 산분피해는 순조 4년(1804)에 발생한 강원도 동해안 산불로 사망자 61명, 민가 2,600호가 소실되었다. 또한 최대 인명피해가 발생한 산불은 현종13년(1672) 강원도 동해안 산불로 65명이 사망하였다. 조선시대 산불 발생 원인은 원인미상(42건) > 실화(10건) > 방화, 낙뢰(3건) > 수렵입화(2건) > 어린이 불장난, 논밭두렁소각, 가옥화재(각 1건)로 나타났으며 지역별 산불발생은 동해안 지역이 39건(56%)으로 가장 많이 발생한 것으로 나타났다. 계절별 산불발생은 봄철기간 산불이 46건(73%)으로 가장 많은 것으로 나타났으며 연중 산불이 가장 많이 발생한 기간은 4~5월로 현재의 산불위험시기와 유사하다. 산불관련자에 대한 처벌의 경우, 방화자 및 실화자에 대해서는 유배, 관직박탈, 효시 등의 처벌기록과 관리지역 책임자에 대한 문책이 기록되어 있다. 결론적으로 조선왕조시대의 경우에도 산불 위험성과 심각성에 대해 여러 문헌에서 기록되어 있는 것을 알 수 있고 현재 우리나라 산불발생 기간 및 지역 패턴과 유사한 것으로 나타났다.

서론(Introduction)

조선시대에도 역대 왕조별로 산불발생 상황이 어떠하였는지를 구명해보기 위하여 조선왕조실록, 승정원일기 등 참고문헌을 통하여 산불발생과 관련된 사항을 추출한 후 분석하여 당시의 산불발생특성은 어떠했으며, 산불종별, 계절별 특성 및 산불발생위험지역 구분, 강풍과 산불발생과의 관계 등을 분석하여 조선시대의 산불특성을 구명해 내고, 당시대에 발생된 산불이 우리에게 주는 교훈을 도출해 보고자 한다. 또한 산불과 관련된 행정 및 처벌에 관한 사항을 정리하였고 본 연구를 통해 조선왕조시대 산불정책을 토대로 현 우리나라 산불정책 방향을 되짚고 향후, 발전시켜나갈 산불정책을 마련하는데 도움이 되고자 한다. 본 연구에서 사용된 연도와 날짜는 현재의 양력으로 변경하여 기술하였으며 원문에 대한 번안문은 음력으로 정리하였다. 미기록된 산

불발생일자는 관련 문서 분석으로 통해 표기하였다.

재료 및 방법(Methodology)

조선왕조시대의 산불정책을 분석, 정리하기 위해서는 공식적인 역사기록서를 토대로 이루어져야 한다. 본 연구에서 분석된 역사기록서는 조선왕조실록, 승정원일기, 대전회통, 고려사절요, 경국대전, 대전속록, 조선후기산림정책사, 국역비변사등록 등에 대해 산불정책과 관련된 내용을 분석, 정리하였다. 본 연구에 활용된 역사 기록서 분석은 지난 40년간 한국고전번역원에서 구축한 DB자료를 토대로 이루어졌다. 일부 역사기록서 및 고전에 대해서는 번역작업이 진행 중이며 번역되지 않는 기록 연대에 대해서는 조선후기산림정책사(배재수 외3, 2002), 조선사외사(차성찬, 1947), 대전속록(조선총독부 중추원, 1935) 드의 자료를 토대로 보완하였다. 본 조사분석에서 나온 내용을 바탕으로 산불예방분야와 구휼등 민심안정분야로 나누어 정리하였다. 분석한 조선시대 역사기록서에서 아직 발견하지 못한 산불기록이 남아 있어 향후 이에 대해 지속적으로 문헌 검색 및 분석이 진행될 필요가 있음을 밝혀둔다.

결과 및 고찰(Results and Discussion)

왕조별 산불현황

산불발생 원인을 살펴보면, 총 63건의 기록에서 산불발생 원인이 명확히 기록되어 있지 않은 건수가 42건으로 가장 많고 이후 실화에 의한 산불발생이 10건으로 기록되어있다. 방화에 의한 산불과 여름철 낙뢰에 의한 산불이 각각 3건으로 기록되었고 군대에서 사냥을 위해 불을 놓은 사례가 2건 기록되어 있고 기타 어린이 불장난, 논밭두렁소각, 가옥화재에 의한 산불이 각각 1건씩 기록되어 있다. 조선시대 산불 발생 기록에서 산불이 발생한 일자를 기록한 내용은 전체 63건의 산불발생 기록 중에서 19건만이 정확한 산불발생일자가 기록되어 있다. 표 1은 실제 산불발생 일자와 함께 산불발생이 기록되지 않은 내용에 대해 기록된 날짜를 함께 정리하여 나타낸 것이다. 따라서 분석 자료는 실제 산불발생일자와 차이가 있음을 밝혀둔다. 표 1에서 정리한 계절별 산불발생은 봄철(46건, 73%) > 여름철(11건, 17.5) > 겨울철(6건, 9.5%) > 가을철(0건, 0%)로 봄철기간 산불발생이 가장 많은 것으로 나타났다. 현재 산림청에서 운영하고 있는 산불조심기간인 봄철산불조심기간(2월 1일∽5월 15일)과 가을철 산불조심기간(11월 1일∽12월 15일)에 발생한 산불발생은 51건으로 전체 63건

의 약 81%를 차지하고 있다. 여기서 여름철 산불은 낙뢰로 인한 산불발생의 특이성으로 인해 기록이 남겨져 있는 것으로 판단된다. 또한 12월과 1월 겨울철에도 산불이 발생한 것으로 기록되었다.

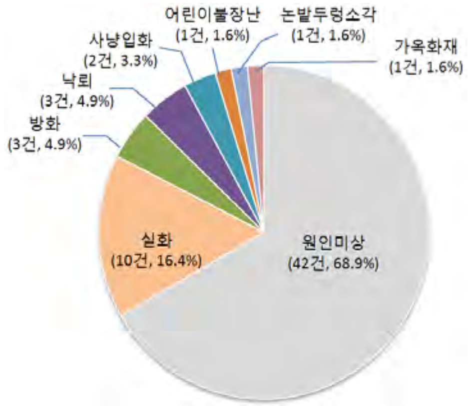

Figure 1. Cause of Forest Fire during Chosun Dynasty

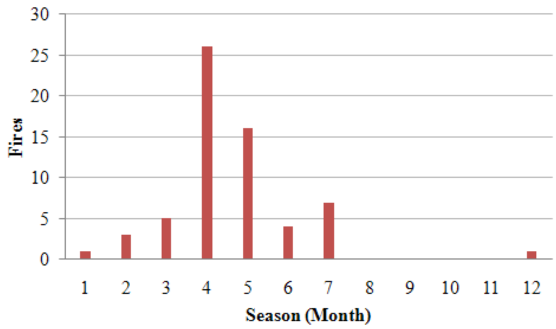

Figure 2. Numbers of Forest Fires by Each Month

조선시대 산불정책

조선왕조시대 산불방지정책은 크게 예방분야와 민생안정에 관한 정책으로 구분할 수 있었고 산불예방분야에서는 산불발생가능지역과 산불보호대상지역으로 구분하여 예방정책을 시행하였다. 산불발생가능지역으로는 화전경작 산림지역, 강무장 등 사냥터, 봉수대 주변 산림지역, 병해충 구제를 위한 입화가능지역이며 왕실묘 주변, 사고(史庫), 소나무 육림을 위한 산림인 금산 또는 봉산, 도성 숲은 산불보호대상지역에 포함되어 산불방지정책을 시행하였다. 민생안정에 관한 정책에서는 산불피해지역 백성을 위로하고 산불피해지 복구를 위해 어사를 파견하여 구휼토록 정책을 펼쳤다. 특히, 산불예방정책 시행을 위반하여 산불을 발생시킨 죄에 대해서는 엄하게 책임을 물어 귀양에서부터 사형에 이르는 처벌을 내렸다. 결론적으로 조선왕조시대에도 산불의 심각성으로 인해 조정 및 지방관서 등에서 여러 방지정책들이 시행되었다는 것을 알 수 있다.

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The analysis for cognition of forest fire danager of structure in Wildland-Urban interface

산림인접지내 건물의 산불위험에 대한 인식 분석

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Abstract

The facilities in wildland-urban interface was a main reason of forest fire ignition and a main subject of protection. It is very important to decide the method of administration and the order of priority for protection of life and property. In this study, we researched a survey about classification and priority of facilities in wildland-urban interface. In results, the recognition rate of high possibility facilities for forest fire occurrence was high, but, the recognition rate of facilities which need more intensive protection management was low. The formulation of facilities classification in wildland urban interface and promotion of this system were needed. The officer recognized rice paddy and levee, graveyard and orchard as high possibility facilities for forest fire occurrence. And they recognized cultural assets and housing as facilities which need more intensive protection management

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요 약

산림 인접 시설은 산불의 발화원이자 주요 보호대상으로써, 이에 대한 관리와 소방 우선 순위의 결정은 인명과 재산의 보호를 위해 매우 중요하다고 할 수 있다. 본 연구에서는 이에 대한 설문조사를 실시하여 인접시설의 대상물과 우선순위에 대한 조사를 실시하였다. 설문조사결과 산불발생 취약대상에 대한 인지도는 높으나, 산불보호 대상에 대한 인지도는 낮으므로, 이에 대한 분류체계 수립과 교육이 필요하며, 산불관련 공무원들은 논밭두렁, 묘지, 과수

원을 취약대상으로 인지하며, 문화재와 천연보호림을 보호대상으로 인식하고, 주요 피해 대상은 문화재와 주거 시설이라고 제시하였다

서론(Introduction)

최근 산불은 선진국에서부터 개발도상국까지 최근 인구 증가와 인구의 도시 집중에 따른 도시의 확장으로 인해, 기존 도시지역 지역에 인접한 외곽 산림, 녹지를 도시로 편입하여, 개발하여 왔다. 이러한 녹지대는 거주민의 건강, 경관을 위해 쾌적한 환경을 제공하게 되지만, 도시에서 발생한 화재가 산불로 전이되거나, 산불이 도시의 건물로 쉽게 옮기게 하는 매개체가 되고 있다. 최근 2009년 발생한 호주 산불은 이 지역에서의 산불로 인해 극심한 인명피해를 발생시키기도 하였다. 우리나라도 과거 동해안 산불, 양양 산불 등 대형 산불 사례에서 민가 및 건물이 소실되는 피해를 입은 바 있으며, 특히, 원자력 발전소와 공공시설이 위협받기도 하여, 이를 위해 특별한 소방대책을 수립하기도 하였다. 따라서, 본 연구에서는 산불 발생 시 인명과 재산을 효과적으로 보호하고, 효율적인 진화 및 방재 대책을 수립하기 위한 대책 중 하나로 인접지에서의 산불 발생 시 우선적으로 진화 및 보호해야 할 대상을 파악하고, 산불이 발생할 수 있는 취약 대상을 지정함으로써, 산불 감시의 우선 순위와 산불 보호를 위한 우선 순위를 지정하고자 하였다. 이러한 산불 위험 지도의 제작의 사전 단계로써, 산림 인접 위험 시설물 관리 기법의 개발에 앞서, 실제 관련 종사자의 의식 조사를 통해 산림 인접 위험 시설물에 대한 의식 수준을 조사하였다.

재료 및 방법(Methodology)

2.1 조사지역 및 방법

설문 대상지역은 산림청 과거 산불통계를 활용하여 경상북도를 선정하였다. 산림청 발간 산불 통계에 의하면, 경상 북도 지방은 지난 20년 간 가장 많은 산불이 발생하였다. 으며, 해당 지역의 경제 사회적 여건에 따라, 울진군(중소도시형), 봉화군(영농형), 경주시(도시형)의 세 시, 군을 선정하여 2010년 4월부터 직접 방문과면담을 통해 설문 조사 및 전문가 면담을 실시하였다. 조사 시 전통적으로 산불을 담당해온 지방 자치 단체의 산림 부서 외에 일반적인 화재를 진화하는 소방공무원을 동일한 설문지로 조사함으로써, 화재와 관련된 의식을 비교할 수 있도록 조사하였다.

설문지 구성은 공무원의 근무 년수, 담당 년수 등의 일반적인 특성을 파악할 수 있는 문항과 산림 인접지역의 취약대상과 산불 보호 대상에 의식에 대한 내용으로 하였으며, 설문의 측정방법은 변수의 특성을 구명하기 위해 명목 척도 방법과 5점 리커트 척도 방법을 이용한 간격척도 방법을 이용하였다. 소방 공무원들에 대한 설문조사는 산림 담당 업무를 담당하는 공무원과의 의식 차이의 분석을 위해 동일한 문항으로 구성하였다. 조사대상 지역 내 군청, 면 사무소, 국유림 관리소 등을 직접 방문하여 조사의 요지를 설명한 후 설문지를 배부하여, 현장에서 직접 개인적으로 설문지에 기입하는 자기 기입방식(Self- administered)을 시행하였다. 대상 설문지는 산림과 직원 40명, 국유림 관리소 직원 25명, 소방공무원 80명으로 총 145부를 분석에 이용하였다.

2.2 분석 방법

산림 담당 공무원과 소방 공무원의 근무 년수와 같은 일반적인 사항과 산림내 및 인접지역의 산불발생 취약대상 및 산불 보호대상 관련 질문 대한 답변들을 통계패키지 Statistical Packagefor social Science(S.P.S.S) 12.0.1을 사용하여 빈도분석을 실시하였다.

결과 및 고찰(Results and Discussion)

3.1 산림 인접 취약대상 및 산불 보호 대상시설에 대한 인지여부

산림 담당 공무원과 소방 공무원 들의 해당 관리 지역의 산림 내 혹은 산림 인접지역에서의 산불 발생 취약 대상과 산불 보호 대상 지역에 대한 인지 여부를 조사한 결과, 담당 공무원의 해당 관리 지역 내의 산불 발생 취약 대상에 대한 인지도는 높았으나(평균인지도 3.74), 산림 인접 산불 보호 대상에 대한 인지도는 낮은 것으로 조사되었다(평균 인지도 2.72). 이것은 담당지역 내의 산불 예방을 위해 취약 대상에 대해서는 자체적인 분류 체계와 계획을 가지고 있는 데 반해, 산불 보호 대상에 대해서는 상대적으로 계획이 미비하였기 때문인 것으로 사료된다. 따라서 관리 지역 내의 산불 보호 대상에 대한 분류 체계 수립 및 교육을 통해, 산불 발생 시 보호 대상 중요도에 따른 체계적이고 효율적인 지역 단위 산불 진화계획의 수립이 필요할 것으로 판단되었다.

3.2 산림 인접 산불 발생 취약 대상물과 보호대상물의 인식에 대한 설문 조사 결과

산림 담당 공무원 들과 소방 공무원들이 산불발생이 가장 잘 일어날 것이라 생각한 2가지 시설물과 산불로부터 보호되어야 할 가치가 있다고 생각하는 2가지 시설물을 선정하도록 설문한 조사결과는 다음 표1, 2와 같다. 또한 산불이 발생하면 가장 많은 피해가 예상되는 시설 2가지를 선정하도록 한 설문 조사 결과는 다음 표 3 과 같다.

설문 조사 결과 담당 공무원들은 산불 발생 취약 대상으로 논 · 밭두렁을 지목하였으며, 그 다음으로 산림 관련 공무원들은 묘지를 지목하였으며, 소방 공무원들은 과수원을 산불발생 취약 대상으로 인식하고 있었다. 이는 최근 논 · 밭두렁 및 과수원에서 발생하는 영농산불이 다발함에 따라 이러한 대상을 주요 산불 발생 취약대상으로 인식하는 것으로 사료된다. 또한, 산불 보호 대상에 대한 인식 조사결과 공무원들은 사찰 등 문화재가 가장 우선적인 보호대상으로 인식하고 있었으며, 그 다음으로 천연 보호림을 보호 대상으로 인식하고 있었다. 이는 최근 양양 산불과 남대문 화재와 같이 문화재의 화재로 인한 소실 시 사회적 영향이 크기 때문에 우선적인 보호 대상으로 인식하는 것으로 보인다. 또한, 산불 발생 시 피해가 예상되는 시설에 대한 인식조사 결과 산림 관련 공무원 들은 문화재 시설이 가장 피해가 예상된다고 지적한 것에 비해, 소방공무원은 주거 시설이 가장 큰 피해를 입을 것으로 예상하였다. 따라서 산림 인접 보호 시설에 대한 중요도 설정 시 문화재와 주거 시설에 대해 진화 계획 시 우선권을 부여해야 할 것으로 판단된다.

Table 1. The recognition for damaged facilities

대상	지방자치단체 공무원		국유림 관리소		소방서 소방 공무원	
	N(명)	백분율(%)	N(명)	백분율(%)	N(명)	백분율(%)
묘지	25	0.33	11	0.22	21	0.14
논 · 밭두렁	38	0.51	24	0.48	75	0.50
과수원	3	0.04	5	0.10	25	0.17
무속행위지	9	0.12	10	0.20	24	0.16
송전탑	0	0.00	0	0	6	0.03

Table 2. The recognition for protected facilities

대상	지방자치단체 공무원		국유림 관리소		소방서 소방 공무원	
	N(명)	백분율(%)	N(명)	백분율(%)	N(명)	백분율(%)
사찰 등 문화재	34	0.43	25	0.50	75	0.48
화기물보관소 (주유소, 가스충전소, LPG저장시설등)	11	0.14	9	0.18	21	0.13
천연보호림	29	0.36	12	0.24	47	0.30
자연휴양림	5	0.06	4	0.08	9	0.06
중계탑	1	0.01	0	0.00	5	0.03

Table 3. The damage expectation of facilities

대상	지방자치단체 공무원		국유림 관리소		소방서 소방 공무원	
	N(명)	백분율(%)	N(명)	백분율(%)	N(명)	백분율(%)
농림시설	17	0.23	18	0.36	30	0.36
주거시설	21	0.28	13	0.26	38	0.46
산업시설	5	0.07	0	0.00	7	0.08
군사시설	1	0.01	1	0.02	4	0.05
문화재시설	30	0.41	18	0.36	4	0.05

결론(Conclusion)

조사결과 지자체의 산림 담당 공무원이 전체 근무 년수나 담당 업무 종사 년수가 국유림 관리소와 소방관 보다 다 긴 것으로 나타났으나, 실제 진화 경험은 소방공무원이 높은 것으로 조사되었다. 또한, 담당 구역 내의 산림 내 혹은 산림 인접한 산불 발생 취약 대상과 산불 시 우선적으로 보호해야할 대상에 대한 인지도 조사 결과, 세 기관 모두 3.5이상을 기록하여, 어느 정도 인지하고 있는 것으로 조사되었으며, 국유림 관리소, 지자체 산림과, 소방서 순으로 인지도가 조사되었다. 하지만, 산불 발생 취약 대상에 대한 인지도에 비해 산불 보호대상에 대한 인지도는 낮으므로 이에 대한 표준화된 분류체계 수립과 교육이 필요할 것으로 사료된다. 또한, 산림 내 혹은 산림 인접한 시설물 중 산불 발생 위험 시설이라고 생각되는 시설물에 대한 설문 조사 결과 세 기관 모두 논·밭두렁이 가장 위험한 취약 대상물이라고 인식하고 있으며, 그 다

음으로 묘지를 지적한 반면, 소방서는 과수원을 취약한 시설로 인식하고 있는 것으로 조사되었다. 또한, 산불 발생 시 우선적으로 보호해야할 대상으로 사찰 및 문화재로 답변하였으며, 그 다음으로 천연 보호림을 우선적으로 보호해야 할 대상이라고 답변하였다. 이는 양양산불과 여타 산불로 인한 문화재의 파괴에 대한 사회적 영향이라고 사료된다. 산불 발생 시 피해가 예상되는 산림 내 혹은 산림 인접지의 시설에 대한 설문 조사 결과 산림관련 기관(지자체 산림과, 국유림 관리소)은 문화재 시설이 주요 피해를 입을 것이라고 답변한 반면, 소방 공무원은 주거 시설이 많은 피해를 입을 것이라고 답변하였다. 이러한 이유는 산림 담당 공무원은 실제 대형 산불 시의 경험으로 인한 결과로 사료되며, 소방 공무원은 일반 화재로 인한 출동 경험과 대상 지역 가옥 등의 주거 시설이 실제 산림과 인접해 있기 때문인 것으로 사료된다.

따라서, 이와 같은 설문 조사 결과를 바탕으로 산림 내 혹은 인접 지역의 취약 시설과 보호 시설에 대한 개념 정립의 기초 자료를 제공할 수 있을 것으로 예상되며, 지역단위 산불 방재 계획 수립 시 진화 및 보호 우선 수위 설정에 중요한 자료로 활용될 거이라 사료된다. 향 후 보다 많은 지역의 조사를 통해 세부적인 우선 순위 설정과 제반 지식을 구축하는 것이 필요하다 하겠다.

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The Fertilization Effect on the Growth and Foliage Nutrients of Containerized *Quercus acutissima* at the Forest Fire Damaged Area

동해안 산불피해지에서 시비처리에 의한 굴참나무 용기묘 생장과 엽내 양분변화

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Abstract

The purpose of this study was to investigate the fertilization effects on the growth of containerized Quercus acutissima at the forest fire damaged land. Seedlings aged 1-0 were planted in April 2004 at the forest fired area close to eastsea of Korea. We tested two fertilization treatments: one was different NPK combinations such as control, 3:4:1, 6:4:1, 3:8:1 and 6:8:1 and the other was the level of applications of slow released fertilizer such as no application, 30g, 60g, and 90g/plant. The order of height at NPK combinations was 6:4:1 > 3:8:1 > 3:4:1> 6:8:1> control. As fertilization increased, the height significantly increased. Based on the results, we can recommend 90g NPK = 6:4:1 combination as the best fertilization method in this forest fire damaged area. There were no significant differences in leaf nutrient concentrations and chlorophyll contents. This means fertilization effect occurred in the experiments because trees grew with similar tissue nutrient concentrations.

요약

이 연구의 목적은 동해안 산불지역에서 비료배합 비율 및 시비량이 내화수종인 굴참나무 용기묘의 초기 활착 및 생장에 미치는 영향을 구명하는 것이다. 1년생(1-0) 용기묘를 2004년 4월에 동해안 산불지에 식재하고, 비료 배합비율 시험을 위해 무시비구, 3:4:1(N:P:K), 6:4:1, 3:8:1 및 6:8:1 처리를 수행하였

으며, 시비량 시험은 1주당 UF완효성복합비료 30g 시비구를 표준구로 60g구(2배량구), 90g구(3배량구)를 처리하였다. 굴참나무 수고 생장량은 6:4:1처리구> 3:8:1처리구> 3:4:1처리구> 6:8:1처리구> 무시비구 순이었다. 굴참나무의 수고 생장은 시비량이 증가할수록 뚜렷이 높아져 각 처리간 유의적 생장차이가 있었다. 따라서 산불피해지에 굴참나무 용기묘의 초기생장 증대를 위해서는 N:P:K=6:4:1 비율로 완효성 3배량(90g) 시비를 적용하는 것이 바람직하다. 시비조합 및 시비량에 따른 엽내 양분 농도 및 엽록소 함량은 처리간에 뚜렷한 차이는 없었다. 이것은 특정 양분의 결핍 혹은 과다 현상이 없는 것으로, 양분 농도는 일정 수준을 유지하면서 시비량에 따라 생장이 증가했다는 것은 시비에 의한 효과로 볼 수 있다.

Introduction

전국적으로 크고 작은 산불로 인하여 매년 많은 면적의 산림이 소실되고 있고, 또한 산림이 울창해지면서 대형 산불로 이어지고 있다. 2000년 4월에 강원도 동해, 삼척지역에서 발생한 동해안 산불은 23,794ha란 엄청난 면적의 피해가 있었다. 산불의 확산은 여러 가지 요인이 있지만 동해안 지역과 같은 소나무 단순림은 대형산불로 이어지는 원인이 되고 있다. 따라서 참나무류와 같은 활엽수종으로 내화수림대를 조성하여 산불확산 방지가 필요하다. 산불은 지상부 biomass와 산림내 유기물층을 제거하여 직·간접적으로 산림토양의 물리화학적 성질을 변화시킨다. 또한 산불피해지는 토양침식, 토사유출 및 산사태 발생의 우려가 상존해 있고 양분의 용탈이 심해 건전한 산림으로의 조성이 어려워 조기 복구방법과 산림의 생산성을 지속적으로 유지하기 위한 산림토양 관리가 이루어져야 한다. 본 연구는 비료배합 비율 및 시비량이 내화수종인 굴참나무 용기묘의 초기 활착 및 생장에 미치는 영향을 구명을 위하여 수행하였다.

Methodology

2000년도 4월에 발생한 동해안 산불피해지인 강원도 삼척시 원덕읍 임원리 163임반 다소반 일대의 LTER site의 내화수림대 조성지에서 실시하였다. 2004년 4월에 시험지를 구획하고 굴참나무 용기묘(1-0)를 식재하였으며, 시험지에 대한 토양단면 조사를 실시한 후 토양시료를 채취하여 물리화학성을 분석하였다. 적정 비료배합비율을 구명하기 위한 시비수준별 시험은 선행 pot시험에서 처리효과가 낮은 2:2:1(질소:인산:칼륨) 시비구와 3:4:2 시비구를 제외하

고 무시비구, 3:4:1, 6:4:1, 3:8:1 및 6:8:1 시비구 등 5개 처리를 하였다. 질소비료는 요소, 인산비료는 용과린, 칼륨비료는 염화가리를 이용하여 배합하였다. 시비량 시험은 1주당 UF완효성복합비료 30g 시비구를 표준구로 60g구(2배량구), 90g구(3배량구)를 두었다. 시비방법은 등고선 방향으로 식재목에서 약 10cm 떨어진 곳에 반원형시비를 하였다. 시비처리 전에 수고와 근원경에 대한 기초생장조사를 실시하였으며, 2006년까지 매년 10월에 수고와 근원경에 대한 연간 생장을 조사하였다. 또한 처리별로 잎을 채취하여 양분함량과 엽록소함량을 분석하였다. 처리별 수고 및 근원경 생장량에 대한 유의성 검정은 분산분석(Anova)을 이용하였다.

Results and Discussion

1. 수고 및 근원경 생장

(1) 시비수준별 시험

수고는 질소시비량이 많은 6:4:1처리구가 가장 높아 87.1cm 생장하여 무시비구 36.2cm에 비하여 2.41배 생장하였다. 6:4:1처리구는 다른 4개 모든 처리구와 유의적 생장차이가 있었다(Figure 1). 질소와 인산 시비량이 2배 많은 6:8:1처리구는 생장이 높지 않았는데, 6:4:1처리구 및 3:8:1처리구보다 유의적으로 낮았다. 이들 처리구는 잎이 약간 황변하는 것으로 보아 과다시비에 의한 피해가 있는 것으로 생각된다. 굴참나무 수고 생장량은 6:4:1처리구> 3:8:1처리구> 3:4:1처리구> 6:8:1처리구> 무시비구 순이었다. 근원경 생장은 수고생장과 마찬가지로 6:4:1처리구에서 가장 높았으며 다른 4개 처리구 모두와 유의적 생장차이가 있었다. 또한 6:8:1 처리구는 수고생장과 마찬가지로 6:4:1처리구와 3:4:1처리구보다 유의하게 낮았다. 처리별 근원경 생장은 6:4:1처리구> 3:4:1처리구> 3:8:1처리구> 6:8:1처리구> 무시비구 순이었다. 무시비구 생장률을 100으로 볼 때 각각 164%, 152%, 131%, 124%의 생장률을 보여 생장량이 가장 높은 6:4:1처리구는 무시비구에 비하여 1.64배 더 생장하였다.

(2) 시비량 시험

굴참나무의 수고 생장은 시비량이 증가할수록 뚜렷이 높아져 각 처리간 유의적 생장차이가 있었다. 수고는 완효성복비 표준구, 2배량구, 3배량구에서 각각 26.6, 71.8, 92.7cm 이었으며, 생장량이 가장 많은 완효성복비 3배량구는 표준구에 비하여 무려 66.1cm 더 높았다. 처리별 수고생장률은 표준구를 100으로 볼 때 2배량구 및 3배량구는 각각 270%, 348%가 생장하여 3배량구는 표

준구에 비하여 3.5배 더 생장하였다. 굴참나무의 근원경 역시 시비량 증가에 따라 생장량이 뚜렷이 높아지는 경향을 보여 각 처리간에 유의적 생장차이가 있었다. 처리구별(표준구, 2배량구, 3배량구) 생장량은 각각 5.6, 11.5, 17.2mm이었으며, 생장량이 가장 많은 완효성복비 3배량구는 표준구에 비하여 11.6mm 더 자랐다. 굴참나무의 근원경생장률은 완효성복비 표준구를 100으로 볼 때 2배량구와 3배량구에서 각각 205%, 307% 생장하였다. 이와 같이 삼척지역 산불피해지에서 굴참나무의 시비효과는 매우 크게 나타났다. 따라서 산불피해지에 굴참나무 용기묘의 초기생장 증대를 위해서는 N:P:K=6:4:1 비율로 완효성 3배량(90g) 시비가 적용되어야 할 것이다.

2. 엽내 양분 및 엽록소함량

(1) 시비수준별 시험

굴참나무 묘목의 엽내 질소, 인, 칼륨 농도는 무시비구 보다 시비처리구에서 높았다. 질소와 인은 3:8:1처리구에서 가장 높았으며 칼륨과 마그네슘 농도는 6:8:1처리구에서 가장 높았다. 엽록소함량은 엽내 양분농도와 같이 3:8:1처리구에서 가장 높았으나, 엽 내 양분 농도 및 엽록소 함량 모두 처리간에 유의적인 차이는 없었다.

(2) 시비량 시험

굴참나무 묘목의 엽내 질소 농도는 완효성복비 표준구, 2배량구 및 3배량구에서 각각 1.77%, 1.96% 및 2.13%로 시비량이 많아질수록 농도가 높아 완효성복비 3배량구가 가장 높았다. 인 농도는 완효성복비 표준구, 2배량구 및 3배량구에서 각각 0.31%, 0.35% 및 0.34%, 칼륨 농도는 1.14%, 1.19% 및 1.25%로 시비량이 많을수록 점차 높아지는 경향이 있었다. 또한 칼슘 농도는 1.11%, 1.14% 및 1.15%이었고 마그네슘 농도는 0.18%, 0.28% 및 0.23%로 마그네슘 3배량구를 제외하고는 시비량이 많을수록 농도가 높아지는 경향이 있었다.

엽록소 함량은 완효성복비 2배량구에서 3.89mg/g로 가장 높았으며 표준구는 3.26mg/g, 3배량구는 2.31mg/g으로 나타났다.

시비량별 엽내 양분 농도 및 엽록소 함량은 처리간에 유의적인 차이는 없었다. 시비량이 많아져도 처리간에 엽 내 양분의 농도가 비슷한 것으로 보아 특정 양분의 결핍 혹은 과다 현상은 없는 것으로 보이며, 양분농도는 일정 수준을 유지하면서 시비량에 따라 생장이 증가했다는 것은 시비에 의한 효과라고 생각된다.

Study on Regional Spatial Autocorrelation of Forest Fire Occurrence in Korea

우리나라 산불 발생의 지역별 공간자기상관성에 관한 연구

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Abstract

Forest fire in Korea has been controlled by local government, so that it is required to understand the characteristics of regional forest fire occurrences for the effective management. In this study, to analyze the patterns of regional forest fire occurrences, we divided South Korea into nine zones based on administrative boundaries and performed spatial statistical analysis using the location data of forest fire occurrences for 1991-2008. The spatial distributions of forest fire were analyzed by the variogram, and the risk of forest fire was predicted by kriging analysis. As a result, forest fires in metropolitan areas showed strong spatial correlations, while it was hard to find spatial correlations of forest fires in local areas without big city as Gangwon-do, Chungcheongbuk-do and Jeju island.

요 약

우리나라 산불관리의 주체는 관할시도 행정자치 단체이므로, 산불을 효율적으로 관리하기 위해서는 지역별 산불 발생 특성에 대한 이해가 필요하다. 본 연구에서는 지역별 산불 발생패턴을 분석하기 위해서, 행정구역도를 기반으로 전국을 9개로 분할하고, 각 권역에서 1991년부터 2008년까지 발생한 산불의 위치 data를 사용해서 공간통계적 분석을 실시하였다. 산불 발생 자료의 공간 분포는 베리오그램을 통해 분석하였고, 도출된 공간자기상관성을 가지고 크리깅 기법을 통해 산불발생위험을 예측하였다. 분석결과, 대도시를 포함하는 권역에서는 산불이 강한 공간상관성을 가지고 있었지만, 강원도, 제주도, 충청북도 등의 대도시를 포함하지 않는 지역에서는 산불의 공간상관성이 낮은 것으로 나타났다.

Introduction

Forest fire is one of the typical forest disasters that damages forests extensively in a short time(Choi et al., 2006). Forest fire makes sustainability management impossible by causing variety of biological, economical and social damages such as loss of forest products, decrease in biodiversity and decrease in the number of tourists. Furthermore, according to a recent research, the danger of forest fire is going bigger due the decline in humidity and the number of days with precipitation that are preceded by the increase of average temperature which is caused by global warming(McCoy and Burn, 2005; Sung et al., 2010). Therefore, it is necessary to study more about ways to prevent forest fire.

In this study, the entire of South Korea was classified into 9 areas using the administrative map and the pattern of forest fire occurrence was analyzed by each area. Through the variogram which is one of the Geostatistics, the spatial autocorrelation of forest fire was studied. Since this method could expect the variance of point by exploring the spatial distribution of variables and analyze influence of factors along with the distances, spatial pattern and relationship could be explained.

Materials and Mehtods

3. Study area and Materials

Forest fire occurrence history was collected by Korea Forest Service(KFA). This daily fire point contains information of occurred time and address. The address of fire occurrence was geo-coded to let data have spatial coordinate by using a land registry map from Korea Cadastral Survey Corporation. The point data was converted to density data with 5km quadrats for quantitativeness. The reason we fixed the size of quadrat to 5km is to minimize an error on converting point to quadrat count because the average of polygon area of land registry map which was used for geo-coding was within 25 square kilometer.

4. Spatial Autocorrelation

Forest fire in order to analyze the characteristics of the spatial, spatial autocorrelation analysis was conducted for each region. Spatial autocorrelation is the correlation among values of a single variable strictly attributable to their relatively close locational positions on a two-dimensional(2-D) surface, introducing a deviation from the independent observations assumption of classical statistics(Griffith, 2009). In this study, spatial autocorrelation were analyzed using semi-variogram. The semi-variogram is customarily used in the variogram and therefore, semi-variogram is used to replace variogram in this study. The variogram is a quantitative descriptive statistic that can be graphically represented in a manner which characterizes the spatial continuity(i.e. roughness) of a data set. The mathematical definition of the variogram is described below:

$$r(h) = \frac{1}{2n}\sum_{i=1}^{n}[z(x_i) - z(x_i + h)]^2$$

x = vector of spatial coordinates(with components x, y for our 2D example),
z(x) = variable under consideration as a function of spatial location,
h = lag vector representing separation between two spatial locations, and
z(x+h) = lagged version of variable under consideration.

The variogram us the plot of variance at each separation distance. When the variance no longer increases, the constant variance is called the sill, and the distance at which the variance approaches the variance is called range of regionalized variable. This range is a neighborhood within which all locations are related to one another(Davis, 1986). The spatial structures can be quantified by this range. In theory the variogram value at the origin should be zero. If it is significantly different from zero for lags very close to zero, then this variogram value is referred to as the nugget. The nugget represents variability at distance smaller than the typical sample spacing, including measurement error.

Variogram model is divided into various models by depending on the presence sill and nugget. In this study, constructed spatial data was analyzed by a spherical model. As a result of the analysis of spatial correlation through empirical variogram, the tendency of spatial correlation was reached to spherical model. In addition, compared with gaussian and exponential model, the error of empirical variogram was the smallest among them.

Results and Discussion

1. Regional spatial autocorrelation

According to the experimental results, the presence of metropolitan areas (Seoul, Busan, Daejeon, Daegu, Gwangju), the spatial correlation was evident (Table 1). In the case of Busan▪Ulsan▪ Geongsangnam-do, one city is adjacent to another. Therefore the spatial autocorrelation was slightly wider than other regions. On the other hand, Gangwon, Jeju Island, Chungcheongbuk-do area aren’t shown a clear spatial autocorrelation. When a lot of fires occur, Sill was relatively higher values. Especially in the case of Seoul▪ Incheon▪Gyeonggi area was got high nugget value. The significance of these results, variations of between near local areas are so high. It implied that the variation of the fire occurrence was large at a close distance.

Table 1. Spatial autocorrelation by region. (a) Seoul, Incheon, Gyeonggi-do, (b) Chungcheongbuk-do, (c) Gangwon-do, (d) Daejeon, Chungcheongnam-do, (e) Daegu, Gyeongsangbuk-do, (f) Busna, Ulsan, Gyeongsangnam-do, (g) Jeollabuk-do, (h) Gwangju, Jeollanam-do, (i) Jeju

Region	Nugget	Range(meter)	Partial Sill
(a)	9.263	49,557.564	11.195
(b)	5.429	59,266.348	3.977
(c)	3.024	27,044.084	3.630
(d)	2.706	41,487.976	2.509
(e)	3.493	36,197.672	3.073
(f)	2.318	31,996.906	1.651
(g)	2.661	52,088.582	2.699
(h)	2.097	59,266.348	0.389
(i)	0.322	59,266.348	0.109

2. Prediction of Regional Forest Fire Risk

Finally, vulnerability map was same as the figure 4. Comparing with the actual forest fire data in figure 1, the results was accurately expected. This research had a advantage on forest fire management because maps, as a polygon data, could expect the risk on the unrisen areas in comparison to the raw data.

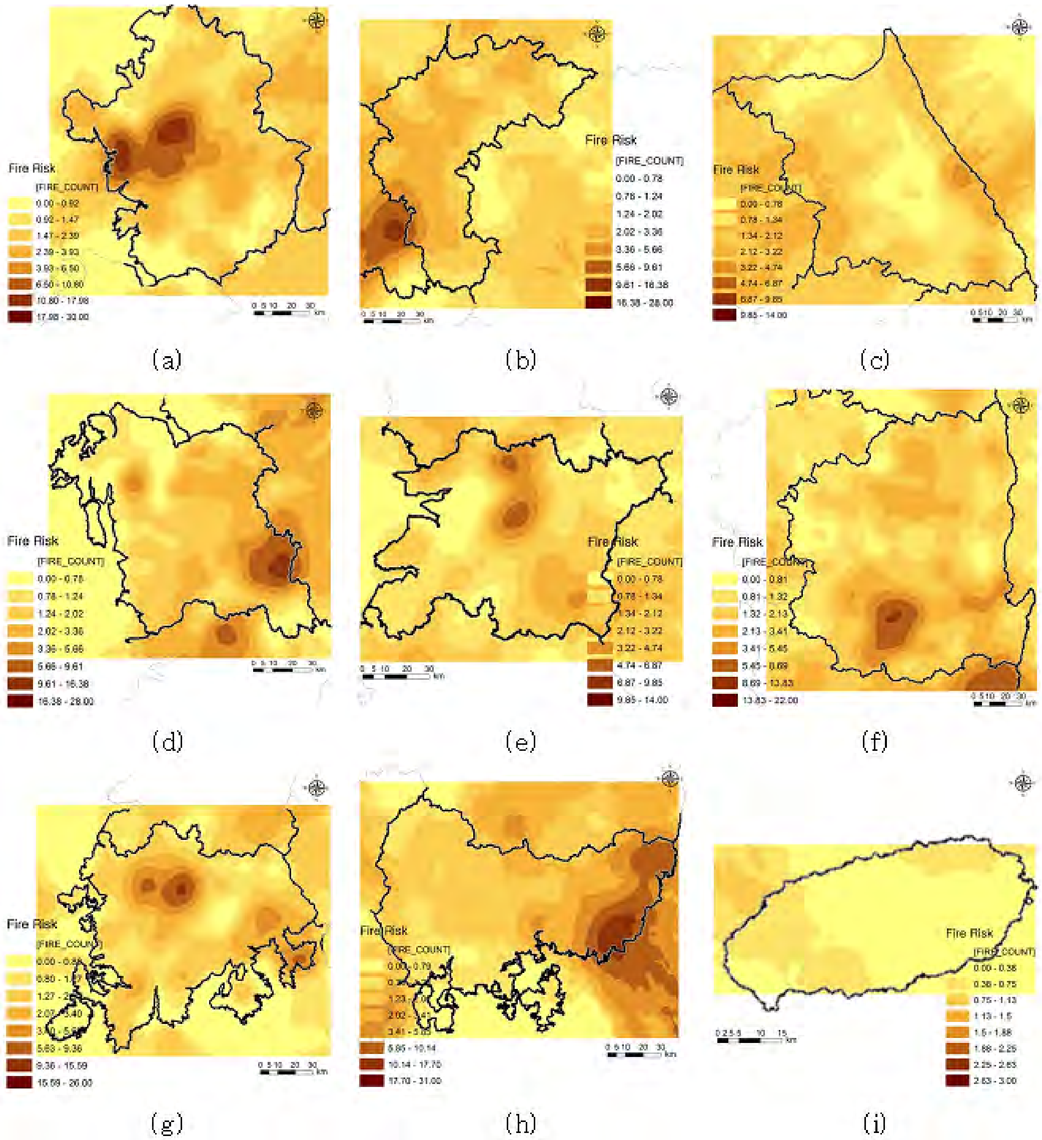

Fig 1. Regional Forest Fire Risk Map. (a) Seoul, Incheon, Gyeonggi-do, (b) Chungcheongbuk-do, (c) Gangwon-do, (d) Daejeon, Chungcheongnam-do, (e) Daegu, Gyeongsangbuk-do, (f) Busna, Ulsan, Gyeongsangnam-do, (g) Jeollabuk-do, (h) Gwangju, Jeollanam-do, (i) Jeju

Conclusion

This research, each administrative district has shown difference of spatial correlation. Especially, the administrative district including major cities has strong spatial group. However, it is hard to identify spatial correlation in Jeju and Kangwon etc. which distribute regular population. Therefore, forest fire prevention strategy should be planned by district with considering spatial correlation.

This study predicted risk of forest fire through only contemplating the forest fire without regard to variables that effect to forest fire. However, this study has performed to predict forest fire, regardless of variables of forest fire and land cover. Therefore, further study should be supplemented by considering various variables and land cover.

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A Research on the Fire Extinguishment Resource Utilization of the Fire Department Specialized in Forest Fire

산불전문진화대의 진화자원 활용실태에 대한 설문조사 연구

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Abstract

On a national scale Forest Fire Extinguishment Ground Teams that are involved a forest fire consist Forest Fire Specialty Extinguishment Teams (city, county, borough) and Forest Fire Extinguishment Teams (national forest). We choose tree area to survey the experience of forest fire extinguishment, average time of arriving at the scene, operating and using equipment situationally (beginning, middle, end), main force equipment when go to put out a forest fire, where the fresh water area for water supply. When forest fire'll be reported workers assign to arrival the scene 40 min at the latest. Main force equipment when go to put out a forest fire is fire-rake followed by the extinguish car, pack-pump followed by the power pump. Main force equipment when go to put out a forest fire is fire rake followed by the extinguish car, pack-pump followed by the power pump. Operating and using equipment are constructing a firebreak(67%) and fire-rake(69%) at the beginning, putting out a forest fire(88%) and power pump(45%) at the middle, cleaning the remainder of fire(60%) and pack-pump(27%) at the end. Reading the ranking of equipment by regional groups, Gyeongju hold helicopters.

요약

전국적으로 산불현장에 투입되는 산불전문진화대(지상진화대)은 크게 2팀으로 산불전문예방진화대(시, 군, 구), 산불진화대(국유림)팀으로 구성되어 있

으며, 3개소 지역을 선정 하여 산불진화 경험, 현장도착 평균소요시간, 상황(초기, 중기, 후기)에 따른 작업 및 주 사용 장비, 산불 진화 시 주력 장비, 용수 공급 시 담수지 등에 대한 설문을 실시하였다. 산불 발생시 늦어도 40분이내(96.1%) 현장 도착 할 수 있도록 배치 되어 있었으며, 주력장비에 대한 설문 조사는 불갈퀴 > 진화차량, 등짐펌프 > 동력펌프 순으로, 상황에 따른 작업 및 주 사용 장비로는 초기에는 방화선구축(67%,작업)과 불갈퀴(69%), 중기에는 산불진화(88%,작업)와 동력펌프(45%), 후기에는 잔불정리(60%) 와 등짐펌프(27%)가 가장 높은 순위로 나타났다. 지역별 장비 순위를 보면 헬기를 보유한 경주의 경우 산불진화시 헬기(67.8%)에 의존하는 경향을 보였다.

서론(Introduction)

우리나라는 전 국토의 65%가 산으로 둘러싸여 있어 주5일 근무제가 정착되면서 산을 찾는 사람들의 발걸음이 국내 어느 산에서도 끊이지 않고 있는 실정이며, 2007년부터 2009년 12월 31일까지의 산림청 통계에 따르면 전국적으로 1,377건의 산불이 발생 하였으며 피해면적이 1,837.88(ha), 피해액 4,705,809(천원)으로 나타나 산불관리의 필요성이 심각하다는 것을 보여주고 있다. 이는 연평균 피해면적 3,635(ha)으로 우리나라 산림면적의 국토의 0.057%의 산림이 훼손되고 있었다. 특히 경북지역의 산불발생 건수가 280건으로 가장 높게 나타났으며 피해면적 또한, 860.92(ha)로 가장 크게 나타났다.

산불은 성능 좋은 진화자원과 수준 높은 진화인력의 다양성을 요구하는 역동적인 재난사고이다. 진화자원은 지상 및 공중진화자원으로 구분되며, 지상진화 자원은 지상 진화대원, 수작업 도구, 차량 등으로, 공중진화 자원은 항공기(고정익, 헬기)로 구분할 수 있고, 자원을 분류하는 것은 사고 담당자가 진화 목적에 알맞은 적합한 자원을 운용 하도록 명령을 내릴 수 있도록 하기 위해서다.

그러나 최근 우리나라 산불현장에서 보면 민, 관 군 등의 인력과 장비가 많아 동원되어도 동원된 진화자원의 효율적인 배분과 지휘가 미흡하다는 지적이 많았다. 효율적인 산불진화를 위해서는 여러 종류 진화자원의 가용성과 유용성을 대해 산불현장 지상 진화 행동 매뉴얼과 각 종 진화 자원들의 최적 배치와 문제점에 대한 많은 연구들이 시행되고 있다.

따라서 본 연구에서는 진화자원 중 지상진화 자원의 실태 조사 및 현황을 알아 보기 위하여 3개소지역을 선정하여 설문 & 현장 기존 기록 조사를 하여 산불진화에 경향 및 문제점을 알아 보고자 한다.

재료 및 방법(Methodology)

전체 산불 발생의 21.96%를 차지하고 있는 경북지역(경주, 봉화, 울진)의 산불예방전문 진화대 및 산불진화대(국유림)를 직접 방문하여 산불전문예방진화대의 산불진화 경험, 신고 접수 후 현장도착 평균시간, 상황(초기, 중기, 후기)에 따른 작업 및 주 사용 장비, 산불 진화 시 주력 장비, 용수 공급 시 담수지 등에 대한 설문조사를 실시하였다.

설문 대상(Table 1)은 경주, 봉화, 울진 3개소 지역의 산림공무원 및 산불예방전문 진화대, 산불 진화대(국유림), 감시원, 의용소방대의 인원수를 표로 나타낸 것이다. 이중 산불에 관련하여 전문적이고 지속적인 활동을 하고 있는 산불예방전문진화대 및 산불 진화대(국유림)에 소속 되어 있는 175명에 대하여 산불진화 경험에 대하여 설문조사를 하였다.

Table 1. Forest fire brigade in three location

	Gyeongju	Bonghwa	Uljin	total
산림공무원	20	15	9	44
산불예방전문진화대	40	40	44	124
산불진화대(국유림)	-	20	31	51
감시원	305	95	138	538
의용소방대	976	450	494	1,920

결과 및 고찰(Results and Discussion)

설문조사대상자의 경우 산불진화의 경험이 1~3회의 경우 28%, 10회 이상의 대원이 58%로 산불진화에 전문성을 가진 대상자들로 설문조사를 습득하였으며, 산불 발생시, 0~30분 이내(69.5%), 0~40분 이내(96.1%)로 늦어도 40분 이내에 산불현장에 도착 할 수 있도록 배치되어 있었다.

현 사용중인 주력장비 대한 설문 조사의 결과 불갈퀴(27.1%), 등짐펌프(26.7%), 진화차량(25.1%), 동력펌프(21.1%)로 비슷한 성향을 볼 수 있었으며, 용수공급에 대한 담수지의 경우 하천 및 냇가(49%), 호수(31%), 강(14%) 순으로 나타내었다.

또한 산불진화작업을 초,중,후기 작업을 단계적으로 설문 조사한 결과(Table 2.)로 초기 작업은 방어선구축, 중기작업은 산불진화, 후기작업은 잔불정리로 나타내었으며, 현재 사용중인 장비 중 살수장비인 동력펌프의 경우 주력장비에는 포함이 되나 실 사용되는 경우가 적은 것으로 나타났으며 산불진화

시 진화차량과 헬기에 의존하는 경향을 보이고 있다. 헬기를 보유하고 있는 경주시의 경우 헬기진화(67.8%)에 상당부분을 차지하였다. 따라서 살수가 가능한 장비 중 산불진화에 큰 비중을 차지하는 장비들을 보유 시 그 장비에 의존하여 다른 장비들의 활용성이 떨어질 것으로 예상되었다.

Table 2. Operating and using equipment situationally(beginning, middle, end)

The beginning	Works	방화선구축(67%)	산불진화(26%)	지대물제거(5%)
	equipments	불갈퀴(69%)	진화차량(14%)	동력펌프(11%)
The middle	Works	산불진화(88%)	방화선구축(7%)	가지제거(4%)
	equipments	동력펌프(45%)	진화차량(24%)	헬기(12%)
The end	Works	잔불정리(60%)	산불진화(38%)	방화선구축(2%)
	equipments	등짐펌프(27%)	불갈퀴(27%)	진화차량(25%)

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Differences in bird communities by postfire restoration

산불 후 복원방법에 따른 조류 군집의 차이

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Abstract

We examined differences in bird communities in relation to characteristics of habitat structure in a pine forest, Samcheok, South Korea. An unburned stand, a stand burned 7 years earlier and then naturally restored, and a stand where Japanese red pine *Pinus densiflora* seedlings were planted after the fire were used for the survey. Habitat structure was dramatically changed by postfire silvicultural practices. Number of stand trees, shrubs, seedlings, snags, and vegetation coverage were significantly different among study stands. We made 1,421 detections of 46 bird species during 23 separate line transect surveys per stand between February 2007 and December 2008. The mean number of observed bird species and individuals, bird species diversity index (H0), and Simpson's diversity index (Ds) were highest in the unburned stand and lowest in the pine seedling stand. There were more species and individuals of forest-dwelling birds in the unburned stand than both burned stands.

요약

강원도 삼척 산불피해지역에서 복원방법에 따른 서식지 구조의 변화 및 이에 따른 조류 군집의 차이를 파악하였다. 서식지 구조의 경우 특히 교목, 관목, 치수, 고사목의 수 및 엽층별 피도량에 있어서 산불 및 산불 후 복원방법에 따라 크게 차이를 보였다. 산불미피해지와 산불피해 후 조림지, 자연복원지에서 2007년 2월부터 2008년 12월까지 총 23회에 걸쳐서 선조사법을 통해 졸

류조사를 실시하였다. 그 결과 총 46종이 1,421회에 걸쳐서 관찰되었으며, 관찰된 평균 조류종수, 개체수, 종다양도지수 및 Simpson 다양도지수 모두 산불미피해지에서 높게 나타났고, 조림지에서 가장 낮게 나타났다. 특히 산림성 조류의 경우에는 산불피해지에 비해 산불미피해지에서 높은 관찰 종수 및 개체수를 보였다.

Introduction

Forest fire is one of the major disturbance agents in forest ecosystems and plays a major role in determining landscape patterns by creating large mosaics of various habitats. Fire affects vegetation, structure, and the wildlife community. Postfire practices, such as removal of woody debris, downed trees, and snags, inadvertently alter a wide variety of habitat structure and wildlife communities, along with those targeted by management activities (Hutto and Gallo 2006). Those forest management activities may result in significant habitat loss on reduction in richness and diversity of forest bird species, and shifts in community composition and relative abundances (Robinson and Robinson 1999). However, changes in wildlife communities in pine forest after a forest fire have been poorly documented and discussed, but concerns over these changes are increasing in Korea, partly as a result of the frequency of large-scale forest fires in South Korea over the last decade (Lee et al. 2008). Also, there have been very few studies of changes in bird communities in relation to changing vegetation structure by forest fire and postfire silvicultural practices in pine forest on the Korean peninsula.

We hypothesized that bird species abundance and diversity and bird community composition would be affected by forest fire and postfire silvicultural practices. In this study, we compared bird communities in different postfire silvicultural management stands and the unburned (control) stand in relation to differences in vegetation structure within a pine forest. Here we discuss the implications for managing burned pine forests in South Korea in relation to the bird community.

Methodology

Our study area was located in the coniferous forest of Samchuck, Gangwondo Province, South Korea. The most dominant tree species is Japanese red pine Pinus densiflora. Mongolian oak Quercus mongolica and cork oak Q. variabilis also occur in the study area (Lee et al. 2008). We selected three types of stands within that pine forest: an unburned stand, a stand burned 7 years earlier and then naturally restored, and a stand in which Japanese red pine *P. densiflora* seedlings were planted. To assess the effect of forest fire and silvicultural practices on bird abundance and community composition, we determined species abundance and diversity using line transect surveys (Bibby et al. 2000). The surveys were conducted 23 times in each stand, 1–3 times every other month, between February 2007 and December 2008, between 0500 and 0900 h. Parallel transect lines spaced at 50-m intervals were established in each stand. All birds heard or seen were recorded, along with the estimated distance, and only birds estimated to be within the 50-m belt were used in the analysis. All observed birds landing or hovering—but not those flying across the study area—were recorded.

Stand characteristics were measured at 100 randomly selected points within a 5-m diameter circle on the survey route in each stand. For each tree, shrub, and woody seedling within a circle, we recorded species and number. The volume of coarse woody debris (CWD) was recorded. We classified vertical layer into understory (0–1 m), midstory(1–2 m), sub-overstory (2–8 m), and overstory (8 m). Coverage was classified into the following four categories based on the percentage of cover in each vertical layer, following Lee et al. (2008): 0 (coverage percentage = 0%), 1 (1–33%), 2 (34–66%), and 3 (67–100%).

Results and Discussion

There were significant differences in forest structure among stands. Overstory vegetation coverage was highest in the unburned stand and lowest in the planted Japanese red pine seedling stand after the fire. Sub-overstory and midstory vegetation coverage were highest in the naturally restored stand and lowest in the pine seedling stand. However, understory vegetation coverage was highest in the pine seedling stand than the others. There were more snags, higher volume of downed CWD, and number of shrub stems in the naturally restored stand. Also, number of tree stems was highest in the unburned stand. Number of woody seedlings were highest in the pine seedling stand and lowest in the unburned stand. In the unburned stand, the overstory vegetation was more developed than in both burned stands. Understory vegetation of the pine seedling stand was more developed than in the other stands.

We made 1,421 detections of 46 bird species during 23 line transect surveys in each stand between February 2007and December 2008. There were 717 individuals of 33 species in the unburned stand, 466 individuals of 32 species in the naturally restored stand, and 235 individuals of 29 species in the pine seedling stand. Mean number of species, individuals, bird species diversity index, and Simpson's diversity index were highest in the unburned stand and lowest in the pine seedling stand.

Forest structure was dramatically changed by fire and postfire silvicultural practices (Lee et al. 2008). Dense understory cover is related to lower tree density in pine forests (Moore and Deiter 1992), presumably due to increased light, water, and nutrient availability under sparser tree canopies. Although burning may reduce understory cover initially, over time, increases in that understory cover would be expected. The amount of woody debris is also influenced by the type of treatment, whether it is removed, piled, or scattered. However, postfire silvicultural practice is expected to result in immediate reductions in woody debris (Converse et al. 2006). Vegetation structure and composition are key factors determining habitat selection in birds, and successional changes in habitats through time result in corresponding changes in bird communities. Forestry activities may result in significant habitat loss on the breeding grounds of forest dependent birds, reductions in bird richness and diversity, and shifts in bird community composition and relative abundance(Andrew et al. 2004).

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Development of U-ICT Forest Disaster Management System Based on LBS(Location Based Services)

LBS기반 U-ICT 산림재해관리시스템 개발

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Abstract

LBS (Location Based Service) based on GPS is utilized a variable parts of a traffic, a control of distribution, an insurance, a security and so on. This system is also very useful for disaster management to response a crisis situation like as forest fire and landslide. In order to guide the safe extinguishment duty of fire fighter and the safe of residents, and acquire its exact location information in case of a large scale of forest fire and rapidly landslide, it is very important to monitor the real time coordination data. Forest disaster as forest fire and landslide need to secure the safe for fire fighters and presidents nearby disaster area. In this study is a related for developing the Smartphone applications of forest disaster that consist functions of real-time monitoring, information transmission.

요약

GPS 기반의 위치관제 시스템은 현재 교통, 물류관제, 보험, 보안 등 다양한 분야에서 활용되고 있다. 재난·재해관리를 방재 분야에서도 다양한 형태의 위기 상황에 대응하기 위해 재난·재해 종류 및 규모별로 다양한 정보자원을 이용해야 하고 인적・물적 자원을 활용하여 빠르게 대응해야 한다. 산불 및 산사태는 진화대원의 안전한 작업유도와 주변 민간인의 보호를 위해 재해현장정보를 신속히 파악하기 위해 실시간으로 모니터링, 정보전송 등의 기능이 필수적이다. 본 연구에서는 스마트 폰 및 GPS-CDMA단말기를 이용한 산불, 산사태 등의 산림재해를 사례로 한 ‘자연재해관제시스템’ 개발에 대해 제시하였다.

서론(Introduction)

재해・재난관리 관제 시스템은 재해・재난에 대하여 예방, 대비, 대응 등 단계별 활동을 지원하기 위한 정보시스템을 말한다. 여러 형태의 재해・재난에 대하여 다양한 정보 자원을 이용해야 하고 여러 임무를 맡고 있는 인적 자원과 물적 자원을 활용하여 빠르게 대응해야 한다. 기존의 방재시스템은 여러 시스템으로 개발되어 개별적으로 운용되어 통합 상황 분석과 즉각적인 위험경보 및 대응에 다소 어려움이 따른다. 본 연구에서는 재해・재난 중 산불 현장상황관리시스템과 산사태위험관리시스템 개발에 대한 연구 내용을 발표하고자 한다. 먼저 우리나라 산불은 최근 10년(2001∼2010)간 매년 478건이 발생하여 1,161ha의 산림피해를 입고 있다. 여기서 산불 발생은 대부분 입산자 실화(43%), 논밭두렁 소각(17%), 담뱃불(10%), 쓰레기소각(9%), 성묘객실화(6%), 기타 방화의심 등에 의한 산불(15%) 등 인위적 원인에 의해 발생되고 있어 산불감시활동에 있어 IT를 이용한 적극적이고 신속한 대응체계가 필요하다. 산림청에서는 산불감시원 배치와 산불감시카메라 운영을 통해 감시활동을 벌이고 있다. 전국에 설치된 산불 무인감시카메라는 약 500여대가 설치되어 운영하고 있으나 음영지역이 많고 산림 및 산림인접지에서의 소각행위에 대한 방지 활동이 어려워 산불감시원의 예방 감시활동 역할이 더욱 중요하다. 하지만 일선 시군에서는 산불감시원의 산불예방, 감시활동 사항을 모니터링하기가 어려워 적극적인 산불감시를 위한 활동관리가 어려운 실정이다. 따라서 산불감시원의 활동을 모니터링하여 산불 취약지 및 음영 지역이 발생하지 않도록 하기 위한 효율적인 관리가 필요하다. 한편 산지토사재해의 경우 매년 약 700ha의 산사태가 발생하고 있으나 재해발생장소에 대한 파악이 어려워 기초자료의 축적이 어려운 실정이다. 재해위치에 대한 환경입지 인자 등의 정확한 파악은 향후 재해예측 및 재해재발을 위한 사방구조물 설치에 중요하다. 하지만 재해발생지로의 접근이 어렵고 다양한 정보취득을 위한 장비를 가지고 산지에서 다양한 조사를 실시하기란 쉬운 일이 아니다. 따라서 GPS, 수치지도 등 다양한 지형, 임상정보를 현지에서 손쉽게 취득하고 DB를 실시간으로 전송·저장할 수 있는 시스템 구축이 시급하다.

이에 본 연구에서는 스마트 폰 및 GPS-CDMA단말기를 이용하여 산불과 산사태에 ‘산림재해관제시스템’ 개발 및 위험관리시스템 구축 방향을 제시한다.

재료 및 방법(Methodology)

스마트폰을 이용한 재해재난 관제시스템

재해・재난 관제시스템은 방재업무를 효율적으로 수행하기 위해 구축하는 것으로 재난정보의 수집, 예방활동 그리고 즉각적인 대응을 위한 실시간 정보공유, 명령전달을 위한 예방-대비-대응 단계별 활동지원 최신 정보관리시스템을 말한다. 예방단계 활동은 GIS, GPS등을 이용한 예방 활동 방향과 정책을 도출하고, 인적자원, 물적자원 등의 효율적 자원관리를 통한 실시간 경보체계 구축을 통해 대비시스템 구축을 지원한다. 대응단계 활동은 ICT 기술을 활용하여 효율적인 상황파악과 대응 시 필요한 의사 결정을 위해 신속하고 정확한 정보전달 체계를 구축한다. 재해・재난 관제시스템 핵심기능의 원활한 수행을 위해서 첨단 정보통신 기술기반의 전략적 아키텍처가 필요하다. 그림 1은 재해・재난 관제시스템 블록도를 나타내며 위치지시장치(GPS-CDMA 단말기)에서 재난위치정보를 SMS 메시지로 이동통신사 서버로 전송 후 전송된 데이터를 관제시스템에서 이동통신사 서버에 접속하여 재난정보를 수신한 후 항공영상과 GIS 수치지도에 정보를 제공하는 것을 기반으로 한다. 본 연구에서는 LBS 기반으로 재난재해 위치정보 및 현장상황정보 전송 및 공유 효율화를 위해 재해위치관제시스템과 연동하는 스마트폰 애플리케이션을 개발하였다.

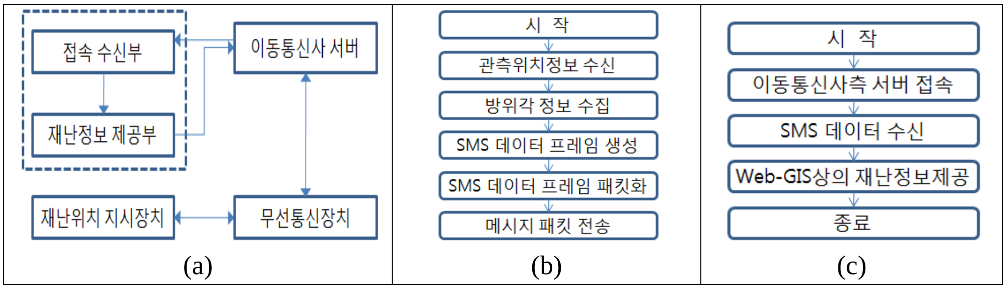

Figure 1. Block Diagram for Disaster Management System (a), Flowchart for Sending a Message of Disaster Information (b), Flowchart to support the Disaster Information (c)

결과 및 고찰(Results and Discussion)

산불

산불현장 진화대원 위치관리 및 산불상황관리를 위해 개발한 스마트폰용 산불현장관리시스템 애플리케이션을 개발하였다. 애플리케이션의 주요 기능은 산불발생위치전송, 사진촬영전송, 동영상촬영전송, 상황보고, 간이확산예측, 산불조사야장작성, 산불등급판정 등으로 구성되어 있다. 이러한 정보는 Web_항공영상기반 산불위치관제시스템과 연동하여 산불을 실시간 관리, 운영할 수 있다. Figure 2는 스마트폰 산불현장운영 애플리케이션의 메인화면 및 사진촬영을 위한 기능 구현 화면이다.

산사태 발생 또는 토석류 피해지에 대해 필요한 정보(발생위치, 임상상태, 피해상황, 계류개황, 기타 지형 및 지질정보 등)를 수치지도를 통해 현장에서 손쉽게 파악하고 기록된 자료가 디지털 자료로 입력될 수 있는 시스템을 스마트폰에 탑재할 수 있는 시스템을 개발하였다. 주요기능으로는 GPS를 연계하여 정확한 피해지 위치파악, 수치지도를 탑재함으로써 다양한 지형 및 지질정보를 화면터치만으로 입력하고 주변환경에 대한 정보를 파악할 수 있다. 또한 이러한 정보를 실시간으로 메인서버로 전송할 수 있는 시스템을 구축함으로써 재해실무 담당자들이 현장에서 조사한 내용을 공유하고 연구 및 행정에 활용할 수 있다.

Figure 2는 스마트폰 산불현장운영 애플리케이션의 메인화면 및 사진촬영을 위한 기능 구현 화면과 산지토사재해조사 애플리케이션의 메인화면이다.

(a) (b) (c)

Figure 2. The Main Scene of Forest Fire Management Tool in Smart Phone Application (a), The Function of Taking Picture included GPS Information (b), The Main Scene of Soil Sediment Disaster Survey Tool in Smart Phone Application (c)

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Liming effects on soil condition of a forest fire burned stand in southern Korea

산불 갱신임분의 토양상태에 미치는 석회처리 효과

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Abstract

After forest fire, a *Machilus thunbergii* stand around an industrial complex in the southern Korea was limed with coarse granular dolomite of 0.0, 2.0, 2.5, 3.0, 3.5, and 4.0 ton/ha. Soil chemical properties and respiration in rooting zone were monitored during 4 years. Soil pH, N, total P increased, whereas exchangeable Al^{3+} content decreased with the increase of liming amount. C/N ratio of soil did not show significant difference among plots with different treatment amount of dolomite. Dolomitic liming increased decomposition rate of organic matter and the result increased organic carbon and total nitrogen. The accererated decomposition would be originated from the combined effect of the increased soil pH and higher microbial activity due to that.

요약

남부지역 공단 주변에서 산불 후의 후박나무 갱신림을 대상으로 석회고토의 양을 달리하여 처리하고 토양화학성과 토양호흡량의 변화를 측정하였다. 석회고토 처리량이 증가함에 따라 토양산도, 전질소, 유효인산 함량이 같이 증가한 반면 치환성 알루미늄은 반대의 경향을 보였다. 토양내 탄질률은 석회고토 처리량에 따라 차이를 보이지 않았다. 석회고토 처리가 유기물의 분해를 촉진시켜 토양 중의 유기물 함량과 전질소 함량을 같이 증가시켜 나타난 결과로 추정된다. 이러한 유기물 분해환경의 개선은 토양산도 교정과 미생물 활성증가 효과의 복합적인 작용에 의한 것으로 판단된다.

Introduction

Reforestation or rehabilitation after forest fire, especially under strong acidic load, needs a countermeasure such as broad-leaved trees' planting and/or liming to alleviate the negative effects of soil degradation. This study was carried to examine the effects of dolomitic liming on the restoration of a *Machilus thunbergii* stand near an industrial complex through investigating soil properties and tree growth as recovery indicators.

Methodology

In 1998, fired forest of 33ha at Mt. Youngchui in Yeosu-city, located in southern Korea, was restored by *Machilus thunbergii* together with dolomitic liming and others were remained in grassland mainly with *Miscanthus sinensis*. For liming treatment ($900m^2$/plot), coarse granule dolomite was used as a soil ameliorator in 6 doses (0, 2.0, 2.5, 3.0, 3.5, 4.0 dolomite ton/ha). We monitored the change of soil chemical properties and soil respiration in 2003.

Results and Discussion

Soil Chemical Properties & Soil Resperation

Liming increased soil pH with increasing dolomite dose amount. For soil target pH (to 5.5), 3.23 $CaMg(CO_3)_2$ ton per ha was required, which was doubled than calculated amount. Liming enhanced the pools of available C and N without change of C/N ratio in mineral soil. It means that the dolomitic liming for the restored stand contributed effectively to nutrition recycling in soil. Also phosphorus availability in soil increased, but not potassium, on the other side decreased labile Al^{3+}, a plant-toxic material. Soil respiration rate increased with liming dose, which indicates root growth and increased soil microbial activity after the liming.

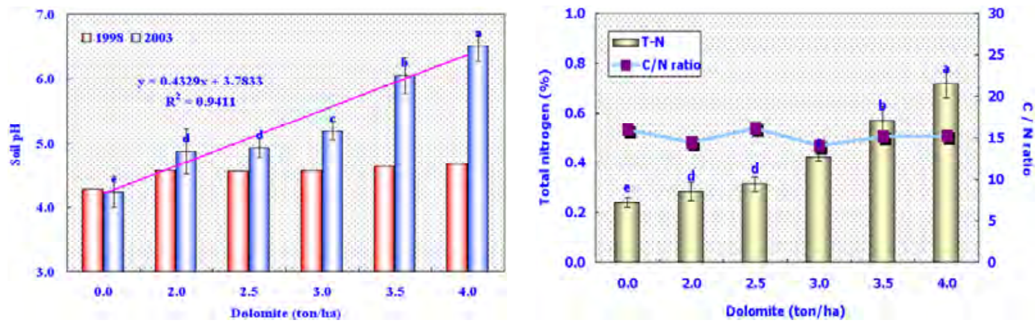

Figure 1. The change of soil pH, total nitrogen and C/N ratio in top soils after liming application

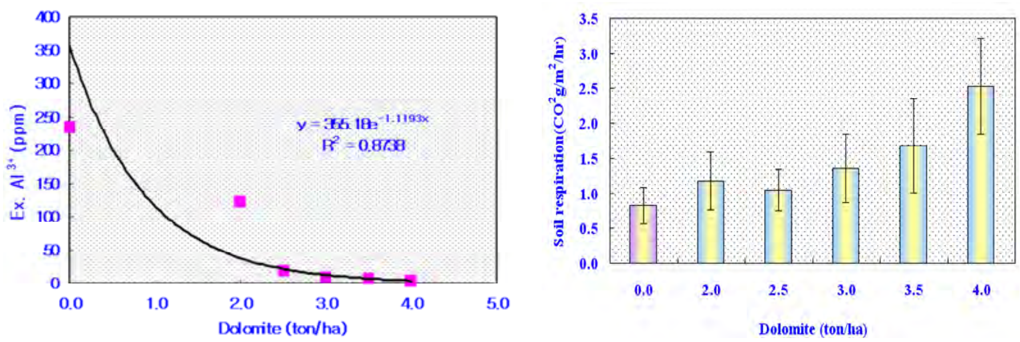

Figure 2. The change of Soil exch-Al and soil resperation rate after liming application

Restoration of forest having very acidic soil and continuing acid loading needs to combat soil acidification risk before and/or after replantation. In this study, dolomitic liming increased soil pH together with decomposition rate of organic matter resulting in increased organic carbon and total nitrogen. The rapid decomposition would be originated from the combined effect of the increased soil pH and higher microbial activity.

Liming with dolomite, an alkaline products, showed several positive effects on restored *Machilus thunbergii* stand after forest fire. Firstly a rise in soil pH and reduction in concentration of exchangeable Al would provide soil ecological benefits. Consequently because this study site is closed to heavy acid deposit sources, the lime application would mitigate the possibilities of negative effects of long-term atmospheric acid deposition.

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The flora of tree pathogens in forest-fired regions in Gangwon province in Korea

강원도 산불피해지역의 수목병원균상 조사

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Abstract

The flora of forest-fired stands in Gangwon province, Korea were surveyed. Powdery midew was annually occurred on black locust(*Robinia pseudo-acasia*) and oak(*Quercus* spp.) trees, and rust, Tubakia leaf spot, powdery mildew, and *Endothia* canker were often occurred on oak trees damaged by fire. Especially in 1st LTER site, pine gall rust was observed on the alternate host, oak tree as well as pines. Pine gall rust would be a potential threat in pine forests with oak trees as a understory vegetation. In artificial plantations of *Pinus thunbergii* in Gosung, 32 kinds of disease including needle cast were reported on 20 tree species. Pine needle cast was severely occurred until 2003, but the trees were gradually recovered and showed good growth of trees since 2004. In Japanese white birch plantations, disease rate by brown leaf spot was annually reported about 30-50%. Severely damaged leaves were early defoliated, and tree vitality would be very low. Thus, it is strongly recommended that the disease should be managed especially in plantations. Maple tar spot, which is a biological indicator of air pollution, was also reported annually in LTER site located in Wonduk, Samcheok. The fruting bodies of *Rhizina undulata*, the pathogen of Rhizina root rot, were observed in pine stands after forest fire for 2 years, but these were not observed any more since 2002. This may due to the loss of vitality of the pathogen by dry conditions in spring season and dense distribution of understory vegetations including brake(*Pteridium aquilinum* var. *latiusculum*), *Artemisia princeps* var. *orientalis*, Black locust. In LTER site in Samcheok, anthracnose of Korean weigela(*Weigela subessilis*), leaf spot of Kudzu vine(*Pueraria lobata*), and witches'-broom of *Rhus chinensis* were severe, but others mimic.

요약

강원도 산불피해지의 수목병원균상을 조사한 결과, 아까시나무와 참나무류에 매년 흰가루병이 심하게 발생되고 있었으며, 산불피해로 수세가 약해진 참나무류에 녹병, 튜바키아점무늬병, 흰가루병, 황색줄기마름병 등 다양한 병해가 발생되고 있었다. 제1영구조사구에서는 특히 소나무 혹병과 중간기주인 참나무류에 잎녹병이 발생하고 있어서 소나무 혹병 발생지에 하층식생으로 참나무류가 분포하고 있는 임지에서는 소나무 혹병의 피해확산이 우려되었다. 고성 조림지의 수목병원균상을 조사한 결과, 해송조림지에서는 해송 잎떨림병 등 20개 수종에 32병종이 관찰되었으며, 해송 잎떨림병은 2003년까지 심하게 발생되었으나 2004년부터는 점차 회복되어 병해를 관찰할 수 없었으며, 생장도 초기보다는 회복된 것으로 관찰되었다. 또한 자작나무 조림지에서는 갈색점무늬병의 피해가 매년 30~50%정도 조사되었으며, 심하게 발병된 자작나무의 경우 잎이 조기낙엽되고 수세가 쇠약하게 되므로 조림지에서는 이 병이 발생되지 않도록 주의해야 할 것이다. 삼척 원덕읍에 위치한 LTER site에서는 공기오염의 생물학적 지표로 이용되는 단풍나무 타르점무늬병이 매년 관찰되었으며, 산불 후 소나무림에서 많이 발생되는 리지나뿌리썩음병의 자실체인 파상땅해파리버섯이 2000년 4월에 발생한 산불 후 8월부터 관찰되기 시작하여 2년동안 계속 관찰할 수 있었으나, 2002년도부터 봄철 건조와 고사리, 쑥, 아까시나무 등 하층식생이 너무 밀식되어 병원균의 활력이 떨어져 자실체가 발생되지 않는 것으로 판단되었다. 삼척 LTER site에서는 병꽃나무 탄저병, 칡 겹둥근무늬병, 붉나무 빗자루병 등의 피해가 심하였고, 다른 병해의 피해는 경미한 수준이었다.

서론(Introduction)

산불로 인한 피해는 재산상의 문제뿐만 아니라 살아있는 동식물과 인간에게 큰 고통과 피해를 주며, 후손들에게 물려주어야 할 아름다운 숲과 환경가치를 잃게 하여 국가적으로도 큰 손해를 끼친다. 1996년 고성 산불 이후 2000년 강원도 고성군에서부터 경상북도 울진군에 이르는 동해안지역에 발생된 대형 산불은 산불이 얼마나 무섭고 두려운 존재인지를 깨우쳐 준 큰 교훈이 되었으며, 산과 더불어 살아가는 농민들의 삶과 지역 경제까지 위축시켜 버렸다. 산불이 발생한 산림에서는 일부 생물에게 유익한 환경제공과 병해충 억제, 관목과 낙엽층 제거 등의 효과도 있지만 생태계의 교란과 수목에 2차 피해가 발생되어 병해충에 대한 내성이 급격히 떨어진다. 특히 산불이 발생된

지역에서는 소나무, 해송, 낙엽송 등 침엽수에 리지나뿌리썩음병 피해가 가장 우려되며, 참나무류에는 부후가 발생되어 재질손실을 가져온다. 산불이 발생된 산림에서 수목병해에 대한 연구는 리지나뿌리썩음병에 대해서만 보고되었을 뿐 다른 병해는 보고된 기록이 거의 없는 실정이므로, 산불 발생 후 나타나는 수목병원균의 경시적 변화에 대한 연구가 향후 다른 연구에 기초적인 자료로 제공되었으면 하는 바램이다.

재료 및 방법(Methodology)

산불피해지인 고성 지역의 제1, 2영구조사구, 송지호 주변의 잣나무, 해송, 자작나무 조림지와 2000년도 산불피해지인 삼척 LTER site에서 수목병원균상을 조사하였다. 조사방법은 조사구내를 순회하면서 이상 증상목의 병징조사와 함께 병해 발생정도를 기록하고 시료를 채집하였다. 채집한 시료는 표징과 병원체의 특징 등을 현미경으로 관찰한 후 참고문헌과 비교하여 병원균을 동정하였다.

결과 및 고찰(Results and Discussion)

고성 제1, 2영구조사구의 수목병원균상을 조사한 결과, 아까시나무와 참나무류에 흰가루병과 병꽃나무 탄저병이 매년 발생되는 것으로 조사되었으며, 특히 참나무류에는 녹병, 점무늬병, 튜바키아점무늬병, 흰가루병 등 다양한 병해가 발생되고 있었다. 참나무류의 튜바키아점무늬병은 2001년도에 발생되기 시작하여 2003년부터 매년 피해가 심해지는 것으로 조사되었으며, 참나무류에는 흰가루병과 튜바키아점무늬병이 가장 피해를 크게 주는 병으로 조사되었다. 제1영구조사구에서는 소나무 혹병이 많이 발생되었으며, 혹병이 발생되면 바람이나 폭설 등에 의해 쉽게 가지가 부러지며, 이 혹은 매면 비대해져서 30㎝ 이상의 혹으로도 자라기도 한다. 혹병은 봄과 가을에 소나무의 줄기와 가지에 녹병포자기와 녹포자기를 만들며, 여름포자퇴와 겨울포자퇴는 참나무 잎에 형성한다. 참나무에는 피해가 그리 심각하지 않지만 어린 소나무가 감염되면 몇 년 내로 고사된다. 제1, 2영구조사구에서 병해피해로는 녹병이 17개 수종에 발생되었으며, 이중 붉나무와 조록싸리의 녹병 피해가 심한 것으로 조사되었다. 해송, 자작나무, 잣나무조림지의 수목병원균상을 조사한 결과, 조림지에서 아까시나무 흰가루병, 참나무류 흰가루병과 튜바키아점무늬병 피해가 전체적으로 심하게 발생되어 있었으며, 해송조림지에서는 20개 수종 32병종이 관찰되

었다. 해송조림지내 해송 잎떨림병은 2000년부터 피해가 심하였으나, 2004년부터는 점차 회복되어 조림지에서 병해를 관찰할 수 없었으며, 해송 생장도 초기보다는 생육이 양호한 것으로 관찰되었다. 따라서 산불발생 후 해송을 조림할 경우 3~4년 정도 관리를 잘해주면 생장이 좋을 것으로 판단되었다. 한편 자작나무 조림지에서는 갈색점무늬병 피해가 매년 발생되고 있었으며, 갈색점무늬병은 잎을 조기에 떨어뜨리고 수세를 약화시키므로 경관 조림시에는 병이 발생되지 않도록 각별히 주의해야 할 것으로 판단되었다. 자작나무 갈색점무늬병 피해율은 매년 30~50%로 조사되었으며, 심하게 발병된 자작나무의 경우 6월말에도 대부분의 잎이 낙엽지고 건전목에 비해 수세가 쇠약한 것으로 조사되었다. 2000년 삼척 산불지역인 원덕읍 LTER site를 조사한 결과, 2001년에는 단풍나무 타르 점무늬병 등 24개 수종 28병종이 관찰되었으며, 산불 발생 후 소나무림에서 가장 많이 눈에 띄는 리지나뿌리썩음병 자실체인 파상땅해파리버섯이 많이 발생되어 있었다. 리지나뿌리썩음병의 병원균인 *Rhizina undulata* 는 소나무의 뿌리를 침해하여 나무를 고사시키는 병으로 알려져 있으며, 리지나뿌리썩음병의 피해는 군상으로 나타나고, 매년 조금씩 불규칙한 원형으로 확산된다. 병원균 포자는 고온에서만 발아하는 특성을 가지고 있어, 산불발생지, 모닥불자리, 해안사구림에서 많이 발생한다. 또한 소나무 뿌리가 리지나뿌리썩음병에 감염되면 처음에는 땅가의 잔뿌리가 흑갈색으로 썩고, 점차 굵은 뿌리로 확대되어 뿌리 전체가 흑갈색으로 변한다. 병든 부분에는 방사상의 흑갈색 균사속이 나타나며, 분비된 수지와 토양입자가 섞여 딱딱한 덩어리가 형성된다. 소나무 의 뿌리가 감염되면 수세가 약해지고 잎이 누렇게 변하면서 소나무가 말라 죽는다. 산불 발생 후 삼척 LTER site에서는 6월 중순경까지는 리지나뿌리썩음병의 자실체를 확인할 수 없었으나, 8월경부터 발생되기 시작하여 2년 동안 계속 관찰할 수 있었다. 하지만 2002년도부터는 자실체가 발생되지 않았는데, 이는 봄철 건조와 고사리, 쑥, 아까시나무 등 하층식생이 너무 밀식되어 리지나뿌리썩음병원균의 활력이 떨어진 것으로 판단되었다. 한편 산불 발생 후 LTER site에서 매년 관찰된 단풍나무 타르점무늬병은 공해에 약한 특징이 있어 공기오염의 생물학적 지표로 이용되고 있으며, 도시의 조경수나 정원에서는 거의 발생되지 않는 병해로 알려져 있다. 삼척 LTER site에서는 병꽃나무 탄저병, 칡 겹둥근무늬병 피해가 심하였으며, 물푸레나무, 아까시나무, 참나무류 등 많은 수종에 흰가루병이 발생되고 있었다. 흰가루병은 수목에 치명적인 병해는 아니지만, 거의 모든 식물을 침해하고 심하게 발생되면 광합성 부족, 양분의 탈취 등으로 생육이 위축되고 수량감소를 초래한다. 삼척 LTER site의 수목병원균상은 산불발생 후 어느 정도 안정화되어 가는 추세였으며, 참나무류와 붉나무에서 병해가 많이 발생되는 것으로 보아 산불 발생 후 피해를 가장 많이 받는 수종인 것으로 판단되었다. 일부 참나무류에는 맹아가 고

사하고 지제부가 변색되어 부후가 진행 중인 참나무가 많이 관찰되었으므로 지속적인 조사의 필요성이 있는 것으로 판단되었다.

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Changes of photosynthetic characteristics of Japanese larch(*Larix kaempferi*) seedlings raised under different CO_2 concentration

서로 다른 CO_2 농도에 따른 낙엽송의 광합성 특성 변화

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Abstract

Larch (*Larix kaempferi*) is an early successional conifer, and one of the most popular species for reforestation in northern Japan from 1960-70's. Recently, we can expect natural regeneration after the disturbances of timber harvest or typhoon damages because mother trees are reaching to the age of reproduction. However, success of regeneration of seedlings depends on the size of forest gap because of light demanding traits in larch species. Therefore, we should evaluate the light use traits of photosynthesis in larch seedlings treated with shading in combination of nitrogen supply. We simulated environmental condition in a forest gap for light use characteristics of regenerated larch seedlings. When long shoot needles started to elongate, three-year-old seedlings were treated with three levels of light conditions (i.e. 0%, 50% and 80% cut) with and without nitrogen supply (2 N kg/hr· yr). After 80 days treatments, we determined light and CO_2 depending photosynthetic rate was measured with an open gas flow system (LI-6400) and composition of chlorophyll a and b, ratio of chlorophyll to nitrogen for acclimation ability to shading condition. Moreover, we examined the relationship between needle morphology or anatomy (A^{mes}/A) and net photosynthetic rate. Relative growth rate of the seedlings was also determined in volume of stem. Based on these parameters, we will discuss the plausible understanding of forest environment for natural regeneration of larch seedlings.

서론(Introduction)

자연교란은 산림의 천연갱신을 촉진하는 요인 중 하나로서 최근에는 벌

채 등의 인위적 교란과 태풍 등의 자연교란 후 천연갱신에 의한 산림재생이 기대되고 있다. 유라시아 북동부에는 낙엽송속수종이 광범위하게 분포하고 있으며 우리나라에서는 1960-70년대부터 광범위하게 식재된 낙엽송이 재생산연령에 도달하였으며 장령림에는 벌목이나 수확으로 인하여 임내의 상층목이 소개되어 있는 곳이 있어 천연갱신이 기대되는 지역이 많다. 본 연구에서는 양수로 알려져 있는 낙엽송의 치수가 임상의 피음이나 소개된 곳에서 자연 발생하여 어떤 생장을 하는지를 생리적, 형태적 반응을 조사하여 천연갱신이 가능한 환경을 수목의 생리적 변화 통하여 해명하는 것을 목적으로 하였다. 또한, 최근 질소침착이 증가하는 경향을 주목하고 광부족과 질소침착의 복합적인 영향을 구명하는데 주목했다.

재료 및 방법(Methodology)

재료는 3년생 낙엽송 묘목을 대상으로 피음격자를 이용하여 차광조건 0%, 50%, 80%의 3조건, 질소처리는 처리와 무처리의 2단계 조건으로 실시하였으며 질소량은 $3kgN \cdot ha^{-1}yr^{-1}$을 처리하였다. 생리적 특성을 조사하기 위해 LED light source와 CO_2 injector system이 부착된 휴대용 광합성 측정기(Li-6400, Li Cor)를 사용하여 광합성 변화를 측정하였고, 측정 후 sample을 채취하여 DMSO법으로 엽록소 함량을 측정하였다.

결과 및 고찰(Results and Discussion)

낙엽송 묘목의 근원경 생장에는 피음처리의 효과가 나타나지 않았다. 이는 생장에 필수요소인 광을 흡수하기 위해서 수고생장을 우선시 하는 경향이 있다. 피음의 정도가 높아지면 광합성작용이 억제되어 광합성 산물이 감소하기 때문에 결과적으로 직경생장은 감소하는 경향을 나타낸 것으로 사료된다.

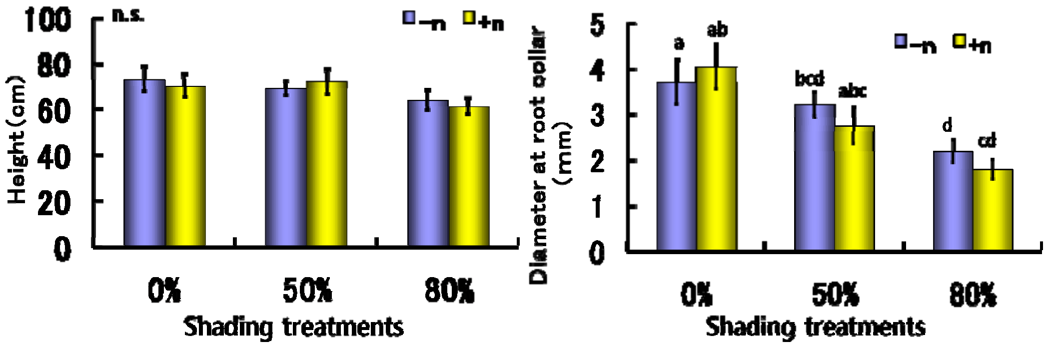

Figure 1. Amount of height and root collar diameter growth of *Larix kaempferi* seedlings

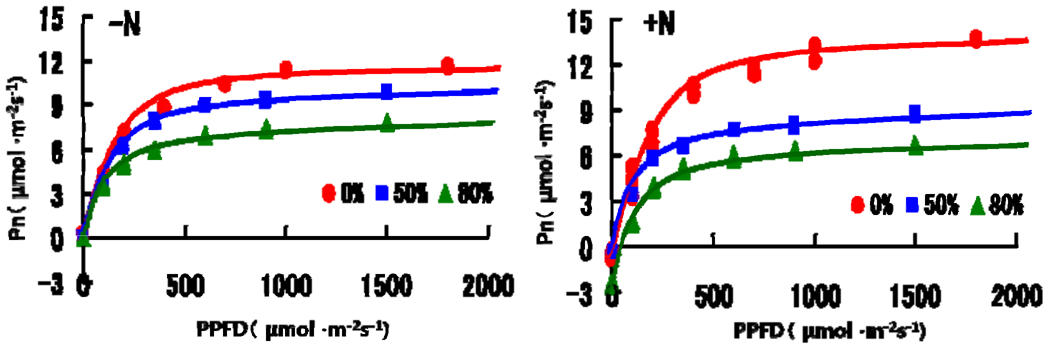

Figure 2. Effect of shade treatment on the photosynthetic rate of *Larix kaempferi* seedlings

낙엽송 묘목의 광-광합성곡선(Light curve)을 측정한 결과 광포화의 광합성속도(Psat)는 차광율 0%>50%>80%의 순으로 높았으며 질소 첨가의 영향은 무차광(0%)에서만 나타났다. 광을 보충하여 운반하는 엽록소량과 조성은 식물의 광합성능력과 밀접한 관계가 있다. 특히 집광부위와 결합한 엽록소b량은 피음의 정도가 높아질수록 증가하여 집광능력이 증가하는 것을 의미한다. 또한, 광이 감소하면 할수록 Chl/N의 비율이 증가하지만 양수인 낙엽송도 침엽은 광이 부족한 상황이 되면 질소를 엽록소에 분배하는 것을 알 수 있다. 그러나, 50% 이상의 피음조건에서는 광포화에서의 광합성 속도는 질소가 존재하더라도 특히 낮은 값을 나타낸다. 즉 낙엽송 치수는 차광율이 높은 광조건에서도 생장이 가능할 것으로 생각된다. 그러나 광합성 관련 단백질합성에 필수요소인 질소가 토양중에 충분히 포함되어 있다 하더라도 피음조건에서는 환원에너지가 부족하기 때문에 충분히 사용이 어렵다. 따라서 양수인 낙엽송 치수는 차광율이 50%이상인 환경에서는 갱신이 어려울 것으로 사료된다.

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Long term change of avifauna referring to the restoration method after the forest fire on Goseong, Korea

고성 산불지역의 복원방법에 따른 장기적 조류군집의 변화상 비교

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Abstract

The avifauna of the forest on Goseong occurred the fire at 1996, were surveyed in long term referring to the restoration method. The birds using the tree layer on the natural restoration area which had kept the dead trees were most not different on the ratio on each year from the unfired forest. But the birds feeding on the tree layer were reduced on the artificial restoration area which had cut the dead tree and planted the new trees. So the artificial control caused the bird community has changed, and the bird ratios of the tree layer gradually recovered on latter. The birds breeding on the tree layer have also reduced on the early stage after the fire on the artificial area more than on the natural area. The birds breeding on the shrub layer have increased after 2 years of the fire up to the ratio of 35% and had the tendency of the decrease gradually. The ratio of birds breeding on herb layer yearly fluctuated on the artificial area more than on the natural area, and it had the tendency showing negative correlation to the contrary with the unfired forest. The densities of the bird species recovered to the level of 90% compared with the unfired forest after 13 years have passed.

요약

1996년 산불이 발생한 고성지역에서 산불복원방법에 따른 장기적인 조

류군집의 변화를 조사하였다. 죽은 나무를 제거하지 않은 자연복원지역은 교목층을 먹이터로 이용하는 조류의 구성비율이 산불이 발생한 이후에도 매년 미피해지역과 유사하여 조류군집이 거의 달라지지 않았다. 그에 비해 죽은 나무를 자르고 식재한 인공복원지역은 교목성 조류가 초기에 크게 감소한 후에 회복되는 경향을 보여 조류군집이 달라졌다. 교목층에 번식하는 조류도 상대적으로 더 낮아져 인공복원이 교목층 이용 조류를 감소시키는 영향을 주었다. 관목층 영소조류는 산불 2년 후에는 35% 비율까지 빠르게 증가하였으며 이후 점차 감소추세를 보였다. 자연복원지역보다는 인공복원지역에서 연 변동폭이 컸으며 인공복원지역은 미피해지역과 관목층 영소 조류의 서식 비율이 서로 상반되는 음의 상관관계를 보였다. 조류 종 서식밀도는 산불 발생 후 13년이 되면서 미피해지역의 약 90%의 수준까지 많이 회복된 것으로 판단된다.

서론(Introduction)

고성군 송지호 인근에서는 최근 1996년과 2000년에 2차례에 걸쳐 대형 산불이 발생하여 많은 피해를 입었으며 그 동안 산불지역의 복원 방법에 따른 변화에 대해 여러 보고가 있다(임업연구원 1996, 정 등 2003, 이 등 2003). 고성 산불지역은 대부분 불에 타 죽은 나무를 잘라버리고 새로 나무를 식재하여 인공복원을 시도한 지역이며 전체의 30ha 정도만 자연 그대로 방치하는 자연복원지역으로 남아있다. 본 조사는 1996년 4월 고성에서 산불이 발생한 이후부터 삼림생태계가 복구되어가는 과정에 조류 군집의 변화를 알고자 하였다. 또한 산불 복원 방법에 따라 조류 군집이 어떻게 변하는 지 알아봄으로 향후 효율적인 복구 방안을 예측하고자 하였다.

재료 및 방법(Methodology)

산불피해 복원방법에 따라 인공복원과 자연복원지역으로 구분하였고 인근에 미피해 송림지역을 대조군으로 선정하여 조사하였다. 산불 초기 조사 내용과 범위는 다른 선행 연구자의 자료를 참고하였으며 2001년부터는 고정 조사지역을 선정하여 표본 조사하는 방식으로 하였다. 2009년 조사에서는 표본의 크기를 100m×100m의 1ha 면적으로 정하고 10~15분 동안에 그곳에서 관찰되는 조류를 기록하였다. 각 산불 특성 지역마다 15개 내외 표본을 조사하였다. 조류 조사 시 비상을 포함하여 목격된 종과 개체, 울음소리를 통해 확인된 개체를 모두 기록하였으나 범위에서 벗어난 개체나 서식지가 다르거나 단지 통

과하는 조류는 자료에서 제외시켰다. 조사월은 매년 번식조류가 안정화되는 5월을 기준으로 진행하였으며 부득이한 경우는 가까운 시기에 조사를 진행하였다. 조류 서식층 구분은 교목층(canopy, tree layer), 관목층(understory, shrub layer), 바닥층(forest floor, ground layer) 3가지로 크게 나누고 그외 조류는 외부 및 기타로 구별하였다. 또한 먹이터로 이용하는 번식지로 사용하는 채이길드(foraging guild)와 영소길드(nesting guild)로 구별하였다. 종 구별과 서식 유형, 길드(guild)별 분류는 원(1981), 이 등(2000)과 함께 유사도 분석은 Browner *et al*. (1990)을 참고하였다.

결과 및 고찰(Results and Discussion)

1996년 5월 산불 발생 이후부터 2009년까지 매년 봄철에 산불이 발생한 지역에 대한 조사에서 교목을 먹이터로 이용하는 조류와 번식지로 사용하는 조류의 비율이 모두 점차 늘어나는 경향을 보였다(Figure 1 & 2). 자연복원지역은 교목을 먹이터로 이용하는 조류의 비율이 14년간 평균 49.4%로 산불 미피해지역의 50.4%로 유사하였고(Figure 1), 서로 해마다 같이 증감하는 상관관계가 있었다(r=0.608, P=0.021, n=14). 자연복원지역에서 교목에 번식하는 조류의 관찰 비율은 산불 초기에 미피해지역보다 낮았으나 7년 후부터는 비슷해졌으며(Figure 2) 서로 양의 상관관계가 있었다(r=0.593, P=0.025, n=14). 이는 죽은 나무를 자르지 않고 그대로 놔둔 자연복원지역의 조류 군집구성이 산불 이후에도 크게 달라지지 않았음을 보여준다. 그에 비해 인공복원지역은 초기에 교목성 조류가 크게 줄었다가 점차 회복되는 경향을 보였으며(평균 31.2%) 번식하는 조류의 비율도 상대적으로 낮고 산불 초기에 크게 떨어졌다(Figure 1 & 2). 이는 산불 초기에 불에 타 죽은 나무를 자르고 인공 식재한 것이 교목성 조류가 떠나버리게 함으로 조류 군집에 교란을 준 것으로 판단된다.

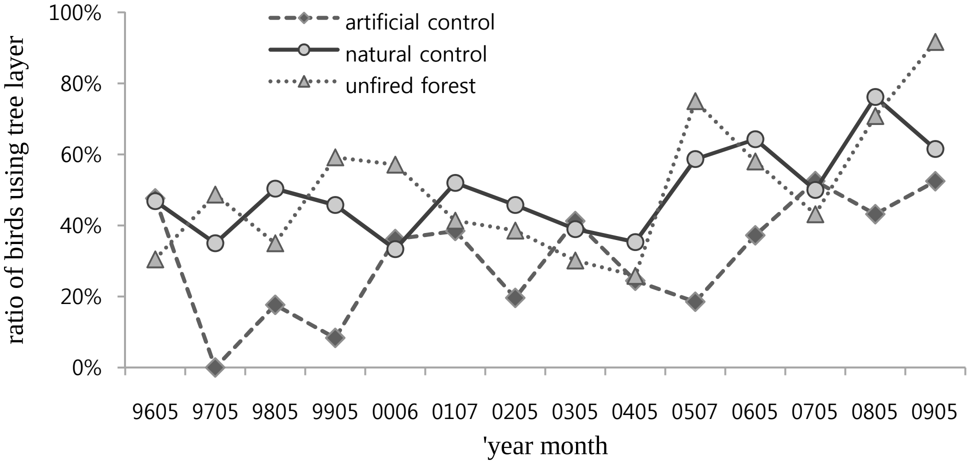

Figure 1. Change of the ratio of birds feeding tree layer referring to the restoration method after the fire on April 1996.

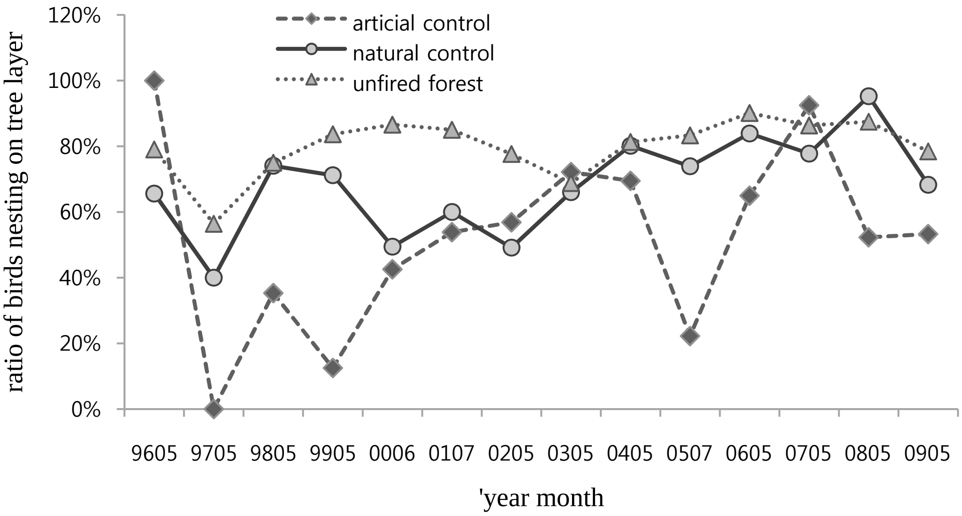

Figure 2. Change of the ratio of birds nesting tree layer referring to the restoration method after the fire on April 1996.

또한 관목층에 번식을 하는 조류의 구성 비율을 보면 산불 직후에는 자연과 인공복원지역 모두 거의 관찰되지 않다가 산불 발생 2년에는 35%까지 빠르게 비율이 증가하였다(Figure 3). 이후 연도에 따른 변화폭이 많았으나 관목층 영소 조류의 비율이 점차 줄어드는 경향을 보였으며 자연복원지역에서 보다 경향이 뚜렷하였다. 그에 비해 인공복원지역은 연도에 따른 변화폭이 많아 산불 이외에도 식재림 종류나 기후와 같은 다른 요인이 함께 작용한 것으로 판단된다. 인공복원지역은 관목층 영소 조류 비율이 평균 20.4%로 미피해

지역과 비슷하였으나 음의 상관관계를 보여 관목층 영소 조류군집이 서로 달라지는 경향을 보였다 (r=-0.591, P=0.026, n=14).

산불 발생 직후에는 관찰되는 조류가 거의 없었으나 이후 13년이 지나면서 조류군집이 많이 회복되었다(Table 1). 미피해지역과 비교해 약 90% 수준까지 평균 관찰종수가 회복되었으며 인공복원지역은 개체수가 더 많기도 하였다. 유사도지수(Ro)는 약 70% 수준으로 비슷해졌다.

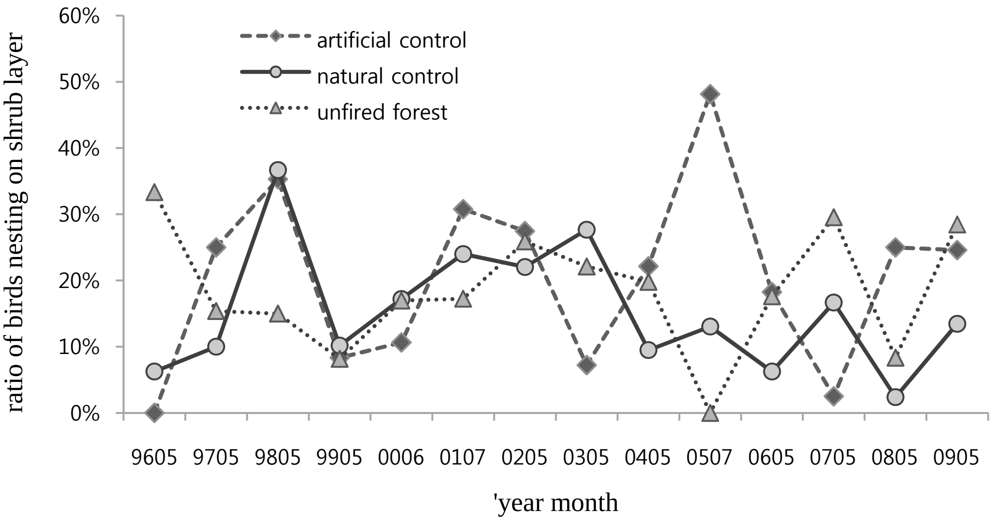

Figure 3. Change of the ratio of birds nesting on shrub layer referring to the restoration method after the fire on April 1996.

Table 1. Comparison of the bird counts on May 2009 referring to the restoration method on Goseong fire area

area	Natural restoration area	Artificial restoration area	Unfired forest Control area
Sample size	15ha	16ha	15ha
Observed species	22	21	25
Total count no.	72	94	88
Average species/ha	3.67	3.81	4.00
Average no./ha	4.80	5.88	5.87

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