발간등록번호 No. 11-1400377-000712-01

연구신서 제 73 호

FOREST LANDSCAPE RESTORATION SUCCESS, EMERGING CHALLENGES AND FUTURE DIRECTION IN THE REPUBLIC OF KOREA

KOREA FOREST RESEARCH INSTITUTE

kfri
KOREA FOREST RESEARCH INSTITUTE

FOREST LANDSCAPE RESTORATION SUCCESS, EMERGING CHALLENGES AND FUTURE DIRECTION IN THE REPUBLIC OF KOREA

Jino KWON

Mani Ram MOKTAN

Joo-Hoon LIM

Sang-Won BAE

DIVISION OF FOREST SOIL AND WATER CONSERVATION
DEPARTMENT OF FOREST CONSERVATION

KOREA FOREST RESEARCH INSTITUTE

Korea Forest Research Institute
57 Hoegiro, Dongdaemun-gu, Seoul, Korea
Tel. + 82-2-961-2635
Fax. + 82-2-961-2649
Web : www.kfri.go.kr/

First edition 2014

ISBN 978-89-8176-274-2 (93520)

_ Preface

It is good news to come out with this book on "*Forest Landscape Restoration Success, Emerging Challenges and Future Direction in the Republic of Korea.*"

This book is intended to serve as a reference for forest researchers, forest practitioners, forest ecologists, conservationists, environmentalists and forest decision makers on forest landscape restoration. This book focuses on three issues: *i) technical and practical process, ii) anticipated issues after forest restoration, iii) and through the view of who may concern on the forest landscape restoration*. The contents are mostly written from English and Korean (abstract in English) literature available. The purpose is to bring out a framework document on forest landscape restoration.

Section 1 and 2 describe background, successive historical national forest plans starting from 1973 to the current national forest plan and significant progress made therein. A systematic and nationally well-coordinated forest restoration approach was undertaken by the Korea Forest Service to address technical and institutional constraints with significant achievements under the leadership of central Government.

As a result of forest reforestation under the various forest plans guided by noble policies of the Government and forest-friendly public participation,

the Republic of Korea has an astounding forest cover of 64.1% of the total geographical area. Not only forest cover, but also growing stock volume increased to 125.6 m^3/ha in 2010 from 9.6 m^3/ha in 1960 with a total growing stock of 800 million cubic meters from 64 million cubic meters, respectively. The benefits of forests to public primarily through production of ecosystem services are immense. According to Korea Forest Service, as on 2010, forest benefits are estimated at 107.52 billion United States (US) dollars. The Korea Forest Research Institute supported the reforestation policy by developing and transferring forestry technology such as developing tree species suited for reforestation and erosion control technology.

Section 3 describes the emerging forest landscape restoration challenges. Forest fires, forest pests and diseases and climate-induced disasters remain threats to forest landscape restoration in the face of climate change.

Section 4 reviews the progress on forest landscape restoration research on priority areas. Effective forest restoration techniques of soil eroded and degraded landscapes, post-fire forest ecosystem recovery methods and techniques, post-mine reclamation techniques, forest pests and diseases control methods and coastal area reforestation techniques are some of the technological advancement made by KFRI to support forest restoration policy.

Section 5 describes about factors that lead to successful landscape

restoration; far-sighted Government forest policies; outside forestry sector policy coordination and implementation; good governance and leadership role played by central Government; integrated planning and coordination of national forest plans and projects by Korea Forest Service, and above all active participation by public, civil societies and international organizations.

Section 6 describes future direction based on the principles of forest landscape restoration. It guides forest landscape restoration approach from site level to landscape level. A general strategy on how and where to start forest restoration including criteria and indicators for measuring progress is given.

I congratulate the Division of Forest Soil and Water Conservation, Department of Forest Conservation for bringing out this publication. In particular, Director, Sang-Won Bae, Dr. Joo- Hoon Lim, Dr. Jino Kwon, Dr. Mani Ram Moktan, and Mr. Moon-Hyun Shin for their credible and good work.

Korea Forest Research Institute

Director General Dr. YOON, Young-kyoon

Yoon Youngkyoon

CONTNETS _

ACRONYMS ························ vii

SUMMARY ························ 1

1. Geography ························ 13
   - 1.1 Location ························ 13
   - 1.2 Geology and Soil ························ 15
   - 1.3 Climate ························ 16
   - 1.4 Forest vegetation ························ 16
   - 1.4.1 Sub-boreal forest ························ 18
   - 1.4.2 Temperate deciduous forest ························ 18
   - 1.4.3 Plantation forest ························ 19
   - 1.4.4 Pine forest ························ 19
   - 1.4.5 Warm temperate evergreen forest ························ 19
   - 1.4.6 High level flat surface forest ························ 20
   - 1.4.7 Wetland forest ························ 20
   - 1.4.8 Urban forest ························ 21

2. History of forest landscape restoration ························ 22
   - 2.1 First National Forest Plan ························ 23
   - 2.2 Second National Forest Plan ························ 24
   - 2.3 Third National Forest Plan ························ 25
   - 2.4 Fourth National Forest Plan ························ 25
   - 2.5 Fifth National Forest Plan ························ 26
   - 2.6 Achievement of forest landscape restoration ························ 28

3. Drivers and challenges of forest landscape restoration ··· 30
3.1 Anthropogenic drivers of forest landscape change ···· 30
3.1.1 Forest fires ··· 31
3.1.2 Conversion of forest land to non-forest land ··· 34
3.1.3 Forest fragmentation by mines and stone quarries ··· 35
3.1.4 Forest pests and diseases ··· 36
3.1.4.1 Pine needle gall midge ··· 38
3.1.4.2 Black pine blast scale ··· 39
3.1.4.3 Fall webworm ··· 39
3.1.4.4 Pine wilt disease ··· 40
3.1.4.5 Oak wilt disease ··· 41
3.2 Transboundary air pollution ··· 42
3.3 Climate change and climate change-induced natural disasters ··· 43

4. Review of forest landscape restoration research in priority areas ··· 46
4.1 Forest restoration in degraded landscapes ··· 46
4.1.1 Forest restoration research strategies in degraded landscapes ··· 62
4.2 Forest restoration in post fire-burnt areas ··· 67
4.2.1 Forest restoration research strategies after fire ··· 74
4.3 Forest restoration in post-mine areas ··· 78
4.3.1 Forest restoration research strategies after mines ··· 84
4.4 Forest restoration in coastal areas ··· 85
4.4.1 Coastal forest restoration research strategies ··· 89
4.5 Forest restoration in pests and diseases affected areas ··· 91

4.5.1 Pine wilt disease ········ 93

4.5.2 Pine needle gall midge ········ 93

4.5.3 Black pine blast scale ········ 94

4.5.4 Fall webworm ········ 94

4.5.5 Forest restoration research strategies of pests and diseases affected areas ········ 95

4.6 Forest restoration strategies for climate change ········ 96

5. Factors of successful forest landscape restoration ········ 101

5.1 Forest policy synergy with related policies ········ 101

5.2 Public participation ········ 102

5.3 Integrated planning and coordination ········ 104

5.4 Good governance and leadership ········ 104

6. Future Direction ········ 107

6.1 Forest restoration at landscape level ········ 107

6.2 Principles of forest landscape restoration ········ 108

6.2.1 Ecological integrity of forests ········ 110

6.2.2 Environmental benefits ········ 110

6.2.3 Livelihood security ········ 111

6.2.4 Adaptive Management ········ 111

6.2.5 Participatory process ········ 113

7. Forest landscape restoration at landscape level ········ 114

8. General strategy to forest landscape restoration ········ 115

9. Measuring progress on forest landscape restoration ········ 116

References ········ 121

_ ACRONYMS

ANOVA	Analysis of Variance
BDMS	Baekdu-Daegan Mountain System
CBD	Convention on Biological Diversity
CO_2	Carbon dioxide
DBH	Diameter at Breast Height
DPRK	Democratic People's Republic of Korea
FAO	Food and Agriculture Organization of the United Nations
FCP	Floor Cover Percentage
FLR	Forest Landscape Restoration
GHGs	Green House Gases
GIS	Geographic Information System
GPFLR	Global Partnership on Forest Landscape Restoration
Gt	Giga tones
Ha	Hectares
IBRD	International Bank for Reconstruction and Development
IUCN	International Union for Conservation of Nature
KFCA	Korea Forest Conservation Association
KFRI	Korea Forest Research Institute
KFS	Korea Forest Service
LCFM	Line + compound fertilizer + microorganism
LTER	Long-Term Ecological Research Site
MASL	Meters Above Sea Level
NDR	Native Ground Restoration
NGOs	Non-Governmental Organizations

RCD	Root Collar Diameter
ROK	Korea, Republic of
SD	Standard Deviation
SDR	Species Diversity Restoration
SE	Standard Error
SER	Society for Ecological Restoration
UNDP	United Nations Development Programme
UNFF	United Nations Forum on Forests
US	United States
WFP	World Food Programme
WWF	World Wide Fund for Nature or World Wildlife Fund in North America

_ SUMMARY

This book summarizes forest landscape restoration success, emerging challenges and future direction in the Republic of Korea. This book is an effort of the Division of Forest Soil and Water Conservation, Department of Forest Conservation, Korea Forest Research Institute to document the history of the Korean forest landscape restoration in the past with major accomplishments and lessons learned and identify emerging drivers of forest landscape restoration and way forward. This summary is derived from the technical book written based on English and Korean (abstract in English) literature available.

The state of Korean forests was characterized by deforestation and degradation causing social and environmental problems such as lack of fuel, heavy soil erosion, severe floods and droughts during and the aftermath of Japanese occupation (1910-1945) and the Korean War (1950-1953).

In order to reforest the denuded and degraded forest land, forest reforestation projects were launched under the 10-year First National Forest Plan (1973-1978). The projects focused on reforestation of denuded and degraded forest land primarily for soil erosion control and fuel wood production with plantation of exotic species. New economic forest zones for land conservation and income enhancement were developed by Korea Forest Service (KFS). The government declared the Nationwide Tree Planting Period (21 March - 20 April) coinciding the planting season seeking active participation

from the public. November was declared as tree tending month to promote thinning, pruning, fertilizing, weeding, and pests and diseases control. The KFS introduced regulations to protect and minimize damage to forests by human through regulating access to planted forests and developing fuel woodlots for people. More than 1 million ha of forests were planted. The 10-year project was completed in 6 years with reforestation of 1.08 million ha achieving more than its planned target. A systematic and well-coordinated forest reforestation approach was undertaken to address technical and institutional constraints.

The Second National Forest Plan (1979-1987) followed to establish large-scale commercial plantation for sustainable timber supplies to meet domestic demand. KFS introduced private forest development fund and expanded the national forests. Since then, various forest policies and regulatory instruments were implemented by the Government in order to achieve reforestation, enhancement of forest protection, and foundation of forest development funds to support private and national forests. Along with the reforestation projects, erosion control was actively undertaken to prevent natural disasters and advancement in the control of forest pests and diseases. Under this plan, 80 large-scale commercial forests were established bringing 325,000 ha under successful reforestation and a total of 1.06 million ha replanted.

The Third National Forest Plan (1988-1997) aimed at establishing multifunctional forests and harmonizing the economic functions and public benefits from forests. The plan focused on establishing the foundation and infrastructure for forest management including forest road construction, forest mechanization, education for foresters and forestry workers. The KFS also implemented forestry income enhancement projects for improving living standards of rural people and public awareness-raising programs highlighting the importance of forests and their conservation. The KFS established natural forest reserves increasing water supplies and creating wildlife habitats. The KFS established commercial forest zones of 32,000 ha and conducted tending operation in over 3 million ha forests. To meet future industrial wood demand, the Government initiated overseas plantation projects with the aim of securing stable and long-term timber supplies.

The Fourth National Forest Plan (1998-2007) entered a transitional phase of forest policies with emphasis on sustainable forest management including recreational benefits. The Government-led forest management policies turned into automatic forest management policies in the private sector based on the capability and discretion of forest owners. To implement the sustainable forest management, KFS consolidated legal and institutional frameworks through amendment of Framework Act on Forest, the Act on Promotion and Management of Forest Resources, the Act on the National Forest Management, the Act on Forest Culture and Recreation and, and the Act on Promotion of Forestry and Mountain Villages in 1997. The plan also developed and implemented policies for improving public benefits from forests including creation of network of recreation forests, water resources conservation, and wildlife protection.

The fifth National Forest Plan (2008-2017) aims “to realize a green nation with sustainable welfare and growth” by sustainably managing forests as key resources for strengthening the nation’s economic development, land conservation and improved quality of human life. The vision clearly encapsulates the new role of forests in carbon sequestration to combat climate change and places strong emphasis on the recreational value of the nation’s forests. To achieve the vision, KFS strategizes: establishment of integrated framework for conserving and using forest ecosystem and biological resources; management of forest land and control of forest disasters; establishment of system for expanding and maximizing public benefits from forests; sustainable forest resources management system; forest carbon management system; forest-based industries for vitalizing forest-related industries and; establishment of overseas plantation forests for global environment conservation. The new paradigm for forest use expands forest for public health including therapy and recreation forests and “from cradle to grave” forests.

As a result of reforestation under successive national forest plans guided by the noble policies, the Government has now an astounding forest cover of 64.1% (6,421,639 ha of the 10,018,808 ha) of the total land surface area. The growing stock volume increased to 125.6 m^3/ha in 2010 from 9.6 m^3/ha in 1960 with a total growing stock of 800 million cubic meters from 64 million cubic meters, respectively.

Besides goods, benefits from forests to public primarily through production of ecosystem services are immense.

As of 2010, forest benefits to public are estimated at 107.52 billion United States (US) dollars, out of which drought and flood prevention accounts for US $ 19.9 billion, erosion control and landslide prevention (US $ 20.7 billion), water quality improvement (US $ 6.4 billion), air quality improvement (US $ 22.3 billion), forest recreation (US $ 16.1 billion), landscape improvement (US $ 15 billion), and wildlife protection (US $ 7.6 billion)

Korea Forest Service 2010

According to the fifth National Forestry Inventory, the Republic of Korea has 528 taxa; 37 ordo, 106 families, 298 genera and 528 species of plants with species diversity estimated at 4.40 which is relatively high, evenness (0.71), and dominance (0.29)

Chung et al. 2013

Forest landscape restoration research in degraded landscapes – site level benefits

The ecological effect of reforestation and erosion control in degraded landscapes assessed in 1995 can be summarized as; soil depth (A and B horizon) of the hilly areas have increased from 1 - 2 cm in 1971 to 11 cm in 1995. Soil depth varied with 4 cm at the upper slopes and 112 cm at the lower valley slopes more than in the beginning of the program 24 years ago. The surface soil at the upper slopes remain shallow which impeded root development of trees except at the base of the lower slopes. Soil texture changed from sandy loam to fine sandy silt loam with increased clay ratio and soil acidity (pH) reduced from 4.1 - 4.5 to 4.6 - 5.5. Root system development, rain interception and wind break effect by overstory trees contributed to stabilizing the surface soils. *Pinus thunbergii* and *P. densiflora* were naturally regenerated as overstory trees but with low density (5 - 20 trees/ha). To form the middle and bottom story, virtually lacking trees, seedling plantation were carried out. The understory trees grew well due to improved microclimate in the last 5 years and tree cover substantially increased. Species that were almost extinct such as *Parus major* (great tit), *Phasianus colchcius* (pheasant), *Streptopelia sp.* (Dove), *Sus scrofa* (wild boar), *Lepus brachyurus* (hare), and *Capreolus capreolus* (Roe deer) reappeared. Harvesting and income generation from non-wood forest products increased.

Lee and Suh 2005

> The Korea Forest Research Institute supported the reforestation policy by developing and transferring forestry technology such as developing tree species suited for reforestation and erosion control technology - Bae et al. 2012

Forest restoration for protection of the Baekdu-Daegan Mountain is important for preservation of its economic, environmental, ecological, and aesthetic values. Development-oriented policies during the past decades have caused fragmentation of forest landscapes. Accordingly, measures to protect the Baekdu-Daegan from development and to restore the degraded ecosystems were put in place. In 2004, the KFS set the criteria for designating protected areas within the Baekdu-Daegan Mountain System (BDMS). The Act on Protection of BDMS came into effect on January 1, 2005 and BDMS was declared as protected areas on September 9, 2005. A total of 263,427 ha (core zone: 169,950 ha, buffer zone: 93,477 ha) have been established. The management strategy of the BDMS was put in place. Soil eroded road slopes were rehabilitated using various restoration techniques and soil erosion successfully controlled by vegetation.

After a large-scale forest fire at Goseong in 1996, many people were interested in the effect of forest fire on ecosystems and the method of forest restoration. A 100 ha Long-Term Ecological Research (LTER) was experimented at Goseong for investigating the effects of fire on ecosystem (soil erosion, water quality, vegetation, and wildlife). After the large East Coast Fire in 2000, about 4,000 ha of a new LTER site at Samcheok, Gangwon-Do, Korea was established. In this site, almost all kinds of research on forest ecology and silviculture; forest meteorology for examination of mountain climate; vegetation changes, insects, birds and small mammals, soil productivity, effects of erosion control methods for reducing post-fire erosion, hydrological influences, characteristics of fire damage forests according to stand structure, and forest stand control for building forest fire resistant forests were studied. Sediment runoff was very severe in the first year after fire but reduced to natural level in the third year. Erosion control by artificial aligning and spreading of coarse woody debris (trees and branches) along the contours has been found very effective. Water quality improved in the year after the forest fire. Tree species recovered by sprouting e.g., *Quercus sp.,* in less severely burnt forests and artificial planting in severely burned forests with herbaceous perennials. The number of species of insects increased at the beginning but later decreased in the burnt forests.

At BDMS, restoration of abandoned mine slopes was experimented 4 years ago. Four vegetation restoration techniques: control (abandoned mine); geo-membrane; woodchip mulching; and rice straw mulching were applied. The result indicated that geo-membrane has the highest vegetation coverage followed by rice straw mulching and woodchip mulching. The use of geo-membrane with soil cover of 30 cm can be an effective technique for vegetation restoration of abandoned mines.

Restoration of forest pests and diseases affected areas include; felling and fumigation, trunk injection of nematicides, aerial spraying of insecticides and silvicultural control through preventive clear-cutting and manual removal of logs for the suppression of pine wilt disease. Among them, felling and fumigation of the infested trees have been the most effective control methods.

More than four decades of successful forest landscape restoration owe to far-sighted Government policies and strategies implemented through successive national forest plans. During the first National Forest Plan, the Republic of Korea established an intensive provisional Government system with a powerful tenacity to restore forests through centralized system. As an integral part of the successive National Forest Plans, the Government introduced forest planning and management projects for establishing forest conservation and development system based on the land use classification and detail scientific reforestation plans. Also strict regulation was introduced to protect reforestation and regulate access to reforested mountains areas. Since forest devastation occurred in rural villages mostly due to excessive fuel wood harvest, fuel woodlots were established to prevent further forest cutting. The production and use of coal briquettes substantially increased in urban areas from 1960s resulting 7% of urban homes using firewood for cooking and heating while rural homes began to use coal briquettes from 1970s onwards only. The substitution of firewood with fossil fuels complemented by rural to urban migration of population resulted decreased firewood consumption contributing to continuous increase of forest cover and stocking from 1960s. The Government also limited domestic timber harvest to 15% of the annual growth of forests.

Secondly, the success has not occurred by chance. The Government policies outside the forest sector significantly contributed in the restoration of forests.

Forest sector policy coordination and implementation of forestry projects between the forestry and allied industrial sectors were synergized to prevent and halt deforestation and forest degradation. For example, introduction of anthracite as wood fuel substitute saved forests from fuel exploitation in collaboration with the Ministry of Commerce and Industry. The national police force was mobilized to implement Government policies and prevent illegal logging, slash and burn agriculture, and regulate public visits in reforestation mountain villages. The Government policy of importing large-size timber logs from outside countries and export in the form of high value finished products greatly reduced the domestic forest dependence on timber products. The excess off-cuts and wood wastes were used for domestic consumption.

The KFS led the success of the national forest plans by not only reforestation of denuded and barren forest land but also creating employment opportunities to the public. Government encouraged and trained local people to establish, to manage village nurseries, and to participate in the planting of trees and implementation of erosion control measures. Creation of nation-wide "tree planting period" and "tree tending period" with active participation of local communities, national organizations, schools and civil societies led to public awareness on environmental issues and valuing forests. Forest fraternities (mutual aid association) were created and leaders were trained to reinforce reforestation activities. Civil societies also actively participated in tree planting and tending operations. Local residents planted and tended trees in the mountain villages.

The cooperation among Government agencies, Non-Governmental organizations (NGOs), civil societies and local communities was mobilized with the good spirit of "Saemaeul Undong" meaning "New Village Campaign". The movement strongly forged and fostered community mobilization, cohesion and participation in bringing about rural development. The first National Forest Plan was directly connected to the Economic Development Plan and National Comprehensive Development Plan. The KFS was established. Institutional strengthening and capacity building of professional foresters and forestry workers delivered services to the public efficiently and effectively. Recognizing the role of forestry in rural development, the KFS was shifted from the Ministry of Agriculture and Forestry to the Ministry of Internal Affairs in 1973 for carrying out effective reforestation.

To bring changes, good governance sought public participation, mobilizing resources and creating a sense of responsibility and accountability in the reforestation programs and projects. In the mid 1970s, the Government of President Park Chung Hee (President Park) advocated the policy of self-sufficiency in domestic food production and consumption and bridged inequity among central, provincial and village agricultural communities in order to promote sustainable economic growth. Thus, he promoted the "Saemaeul Undong" throughout the nation. The movement created a sense of diligence, self-reliance and cooperation among the public and united the reforestation plan to cooperate, implement, protect and conserve forests and concomitantly introduced village projects as economic incentives for reforestation, erosion control, and graveyard preservation. President Park led an efficient and effective administration and played a strong and visionary role. Local forestry associations and county forestry cooperatives provided direct and indirect extension services to support the Government's reforestation policy by offering technical training to rural communities. The KFS and its research organizations supported the reforestation policy by developing and transferring forestry technology such as developing tree species suited for reforestation and erosion control technology. Above all, the astounding reforestation success is the result of close cooperation and collaboration among the Government at central, provincial and municipal level and public who reciprocated with loyalty and trust to overcome the ecological and economic devastation left behind by the colonial regime and the Korean War.

The Republic of Korea has demonstrated success to rest of the nation as a "reforestation model for the world." (Lester Brown, 2008). Lee and Suh (2005) summarized the greatest achievements of the forest landscape restoration as "the first functional improvement of the Korean environment such as erosion control, improvement of soil quality and increasing biodiversity conservation." Nevertheless, the ultimate forest landscape restoration objective of regaining ecological integrity and enhancing human wellbeing is still far from being achieved. Towards realizing the goal of sustainable forest management, forest landscape restoration policy has increasingly shifted from an emphasis of exotic plantation species to native species with a mix of natural regeneration and artificial plantation approaches. In order to achieve these development outcomes, a new kind of challenges surrounds forest landscape restoration in the Republic of Korea. Forest fires, pests and diseases, climate-induced natural disasters and transboundary air pollution are emerging threats to forests and human in the face of climate change.

In order to contribute to the vision of "green nation with sustainable welfare and growth", the Republic of Korea emphasizes sustainable forest management. The KFS strategizes the establishment of system for expanding and maximizing public benefits from forests and forest carbon management system. Forest benefits to public are primarily through realizing ecosystem services. In this context, measuring progress of historical forest landscape restoration success and addressing emerging challenges are essential. To measure forest landscape restoration progress, some underlying principles of ecological integrity, environmental benefits, livelihood security, adaptive management and public participation are to be met. Forest restoration should move from site level to landscape level accommodating a balanced package of forest functions, different interests, biodiversity conservation, watershed management and recreation.

1. Geography

1.1 Location

The Korean peninsula is located between 33°7' and 43°1' north latitude and 124°11' and 131°53' east longitude. It borders with China and Russia in the north and Japan in the south east. It extends about 1,000 km from north to south and 170 km wide from east to west. The Korean peninsula encompasses a total geographical area of 221,000 km^2 (Shin, 2002). Nearly 70% of its geographical area is mountainous. The mountains of Korean peninsula inclines to the east and, thus the eastern slopes are steeper than the gentle western slopes. Gentle terrain surrounds the mountain ranges and valley bottoms have streams and rivers. Mountain Baekdu is the highest mountain (2,744 masl) in the North Korea while in the Republic of Korea (ROK) (Figure 1), Mt, Halla is the highest mountain (1,950 masl) followed by Mt. Jiri (1,915 masl) (KFRI, 2010a). Generally, the Korean peninsula has less than 500 masl high mountains except 1,500 masl high Gaema plateau and 1,000 m high Baekdu-Daegan mountain ranges (KFRI, 2010a).

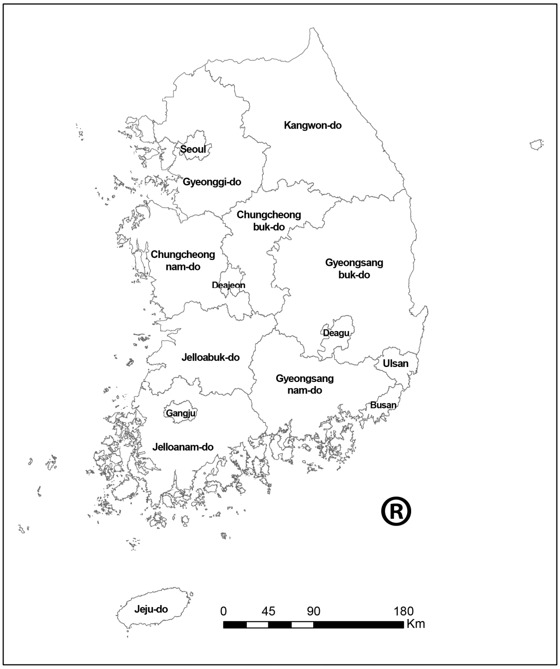

Figure 1. The Republic of Korea

The Korean peninsula main mountain range is Baekdu-Daegan, which is 1,400 km long forming a chain of mountains (Jeong-gan) and 13 secondary branches of mountains called Jeong-Maek (Kim et al., 2007). In ROK, Mt. Baekdu-Daegan stretches 701 km in length from Mt. Janggunbong, Goseong, Gangwon-Do down to Cheonwang Mt. Jiri forming a watershed by 4 main rivers (KFS, 2014). The ROK's total geographical area is 10,018,808 ha with an estimated human population of 50,948,272 persons as on 1 January 2013 (KFS, 2013). According to KFS (2013) out of the total geographical area, 64.1% is forests land, paddy land (11.7%), upland (7.8%), marshy land (1.3%), road (3%), rivers (2.8%), building (2.8%), ditches (1.8%), miscellaneous area (1%), factory (0.8%), orchard (0.6%), pasture land (0.6%), school (0.3%), burial ground (0.3%) and others (1.2%) in 6 provinces, 32 cities and counties (KFS, 2014). ROK ranks 15th in the world by nominal Gross Domestic Product and 12th by purchasing power parity identifying it as one of the G-20 major economies (en.wikipedia.org/wiki/Economy_of_South Korea).

1.2 Geology and Soil

About half of the soil comprised of gneiss complex including granite, granite gneiss and granitic gneiss, which is derived from the protuberance and denudation of granite rocks from the pre-cenozoic era and its degenerated granitic gneiss since the cretaceous period and the diastrophic period (KFRI, 2010a). The soil is classified by region into Gyeonggi metamorphic, Sobaek metamorphic complex and, Jiri metamorphic complex (KFRI, 2010a). The mountains and mountain forests have brown coloured soils, podzol soils, red soils and dark red soils. Brown soil is found in the middle provinces with high temperature and precipitation in summer and in southern provinces where deciduous broadleaves grow. Podzol soil is found in the cold areas e.g., Gaema plateau with a high level of microbiological activity. Red soil is found in the lower hills and gentle slopes on the foot of the mountains. Dark red soil is found in the limestone zone of south Pyongan province and Gangwon province and in the north Chungcheong and Gyeongsang province. Basaltic weathered soil and volcanic ash soil is found in Jeju and Ullung Islands.

1.3 Climate

Located in the temperate zone in the mid latitude, ROK has four distinct seasons. Winter is cold and dry due to northwesterly winds from Siberia. Summers are warm and humid accompanied with monsoon typhoons and rains from the Pacific Ocean. Spring and autumn are relatively short while summer and winter are long. The mean monthly maximum temperature ranges from 23-37°C in August and minimum ranges from -6 to 7°C in January (KMA, 2014). The climate is a mix of continental and oceanic type. The temperature of Seoul in the coldest month is 3.4°C (January) and hottest month is 25.4°C (August) (KFRI, 2010a). The average annual temperature of the Korean Peninsula is lower than other countries on the same latitude. Precipitation distribution pattern decreases from south to north. The annual precipitation ranges from 1,000-1,800 mm/year in the southern region and, 1,100-1,400 mm/year in the central region (KMA, 2014). The southern coastal zones receive the highest rainfall of 1,500 mm/year (Jeju Island receives the highest of 1,800 mm/year) and, south eastern zone receives the lowest of 500-600 mm/year (KFRI, 2010a).

1.4 Forest vegetation

Climate, soil, slope and topography influence the vegetation. About 18,000 years ago, Korean peninsula was under an ice age characterized by tundra vegetation (KFRI, 2010a). Relic boreal forests are still found in the North

Korea and, in high mountains of ROK. As the climate got warmer, most parts of Korean peninsula transformed to cool temperate and warm temperate forests with scattered evergreen trees found in the southern coastal and low lying areas e.g., Jeju Island. According to KFS, forests are broadly classified based on north latitude and mean annual temperature and within the broad classification, variation in forest type and species is given in the Table 1. According to Chung et al (2013), the National Forestry Inventory records 528 taxa; 37 ordo, 106 families, 298 genera, 528 species of which filicinae of pteropsida consist of 23 taxa; 2 ordo, 8 families, 15 genera and 23 species; coniferophytae of gymnospermae consist of 12 taxa, 1 ordo, 4 families, 8 genera and 12 species; monocotyledoneae of angiospermae consist of 72 taxa, 7 ordo, 11 families, 43 genera and 72 species; dicotyledoneae of angiospermae consist of 421 taxa, 27 ordo, 83 families, 232 genera and 421 species. The estimated species diversity stands at 4.40, evenness (0.71) and, dominance (0.29) (Chung et al., 2013).

Table 1. Forest type and species by ecological zones, latitude and temperature

Forest zone	North latitude	Annual mean temperature (℃)	Forest type and species
Sub-boreal forest	Uplands and alpine region	Below 5	Mixed forest: spruce & Korean pines
Cool temperate forest	Between 35 - 43° except for alpine region	5 - 14	Pine forests with deciduous broadleaves, oak trees, bamboos, etc.,
Warm temperate forest	Below 35°	Above 14	Deciduous broadleaves, conifer and deciduous/ evergreen mixed forests and pines

Source: English.forest.go.kr

The forest types and species and associated major faunal species in each forest type as described in the Forest Eco-Atlas of Korea, Research Note No. 384 (KFRI, 2010a) are reproduced below.

1.4.1 Sub-boreal forest

Sub-boreal forests are found above the timberline at Mt. Seorak and Halla. Animals and birds include; whistling hare (*Ochotona hyperborea*), amur goral (*Nemorhaedus goral raddeanus*), black grouse (*Tetrao tetrix*), Nutcraker (*Nucifera caryocatactes*), Siberian rubythroat (*Erithacus calliope*), rosy finch (*Leucosticte arctoa*) and, white-rumped swift (*Chaetura caudacuta*).

1.4.2 Temperate deciduous forest

The deciduous forests cover a total area of 1,660,000 ha (KFS, 2009 statistical yearbook of forestry No. 39) with oak (*Quercus* sp.) as dominant species. Different oak species are; *Quercus mongolica, Q. serrata, Q. aliena, Q. dentate,* etc. The deciduous forest is replacing pine forest in many areas due to ecological succession. Wild animals include; black bear (*Ursus thibetanus ussuricus*, wild boar (*Sus scrofa*), leopard cat (*Felis bengalensis*), Siberian flying squirrel (*Pteromys volcans*), European water shrew (*Neomys fodiens orientalis*), blue and white fly catcher (*Cyanoptila cyanomelana*). Birds are; woodpeckers, owls (*Bubo bubo*), *Phylloscopus sp., Aquila chrysaetos, Falco peregrinus*, *Hypsipetes amaurotis, Stereptopelia orientalis, Parus sp.,* and *Sitta europaea.*

1.4.3 Plantation forest

Pinus koraiensis is endemic to northeast Asia. The natural habitat ranges from southeastern part of China, North Korea to Russia in the far-east. In ROK, it grows in high mountains in the form of natural and plantation and occupies a total area of 230,000 ha (KFS, 2009 statistical year book of forestry No. 39). *Larix kaempferi* plantation forest occupies a total area of 460,000 ha (KFS, 2009 statistical year book of forestry No. 39). Animals found are; red squirrel (*Sciurus vulgaris coreae*), tits and finches.

1.4.4 Pine forest

Two types of pines grow in the Korean peninsula. In the inland areas, *Pinus densiflora* is common whereas *P. thunbergii* grows in the coastlines. Pine forest is reportedly on the decline. In 1974, pine forest covered 49% (3,320,000 ha) of the national forest, however, in 2007 the area declined to 23% (1,470,000 ha) (KFS, 2009 statistical yearbook of forestry No. 39).

1.4.5 Warm temperate evergreen forest

The evergreen forests are found in coastal cliffs of south and west coast and Jeju islands. Because of their evergreen in nature, this forest play an important ecological habitats for breeding animals and birds like roe deer (*Capreolus capreolus*), fairy pitta (*Pitta nympha*), black paradise flycatcher (*Terpsiphone atrocaudata*), *Falco peregrines, Haliaeetus albicilla, H. pelagicus,* *Phalacrocorax sp., Larus crassirostris,* and *Monticola solitarius.* Sea birds and predators found are; *Locustella pleskei* and, *Cisticola juncidis.*

1.4.6 High level flat surface forest

High level flat surface forests are found in Baekdu-Daegan Mountain. Due to strong winds, herbaceous and bushy plants like *Cettia diphone* dominate the high level flat surfaces including Daegwallyeong. The characteristics birds living in open and flat surfaces are; *Emberiza fucata* and *Saxicola torquata.*

1.4.7 Wetland forest

Wetland forests are sub-classified into; i) forest wetlands and, ii) river wetlands or riparian forests. Forest wetlands are found in Mt. Daeam in Yanggu, Gangwon-Do province and the Mujechineup high moor in Ulsan. Wetland forests are patchy but a rich repository of biodiversity mainly amphibians and reptiles. They perform important biogeochemical services such as sedimentation of farm water chemicals into the rivers and streams. Riparian forests are farm-river interface ecosystem, which filters chemicals flowing into the river and streams from farm land and forests. It also serves as an important habitat for plants and birds; *Aix galericulata, Anas poecilorhyncha, Lutra lutra* observed in river wetlands where *Salix koreensis* grows.

1.4.8 Urban forest

These are small patches of forests interspersed around urban cities like Daegu and Seoul. Small animals and birds inhabit this forest; squirrel (*Tamias sibiricus*) and domestic pigeon (*Columbia livia*).

KOREA FOREST RESEARCH INSTITUTE

2. History of forest landscape restoration

From the late 19th century to middle of 20th century, Japanese occupation period (1910-1945) and Korean War (1950-1953) engulfed the ROK. Drought, famine and poor agricultural and economic conditions made the Korean people depend on forests for fuel, timber and food. As a result of deforestation and forest degradation, forest stock reduced to 9.6 m^3/ha in 1960s (KFS, 2012b). Mountains were denuded of forests and during heavy rains, soil erosion was severe. The Korean red pine (*Pinus densiflora*) being pioneer species colonized the denuded areas and covered 60% of the land surface area (KFRI, 2010a). Due to the single-species, however, the pine suffered heavy damages from pine caterpillar, pine needle gall midge and black pine blast. In the last 20 years, pine wilt disease also damaged vast areas of pine forests in the ROK. Since the end of the Korean War, the Government actively pursued the rehabilitation of degraded and destroyed forests through introduction of successive 10 year national forest plans with integrated planning and coordination with outside forest sectors (e.g., introduction of fossil fuels as fuelwood substitute), institutions and public.

2.1 First National Forest Plan

The First National Forest Plan (1973-1978) commenced with the launching of the Forest Rehabilitation Project in 1973. The project focused on reforestation of denuded forests land primarily for fuelwood production purpose. In the 1950s, forests were in a state of extreme devastation due to excessive cutting during and after the Japanese occupation period and the Korean War. To restore the devastated forests, which were causing serious social and environmental problems, like lack of fuel, severe floods and droughts, the first National Forest Plan was devised. According to Bae et al (2012), the aims of the first plan were; the Government to facilitate full participation of the general public for reforestation of 67% of the national land area and provide income opportunities from forest resources; the Government to complete reforestation of 2.6 million ha for the next 20 years and; the Government to mobilize all private and public organizations, agencies and schools near forests for the effort (MIA, 1973). Under this plan, new economic forest zones for land conservation and income enhancement were developed (Lee and Suh, 2005). After the legal and institutional framework preparation in the 1960s, the Forest Rehabilitation Project was finally launched in 1973. The government declared the Nationwide Tree Planting Period (21 March - 20 April) coinciding the planting season seeking active participation from the public (local communities, families, and schools). In addition, November was declared as tree tending period to promote thinning, pruning, fertilizing, weeding, and pests and diseases control. The Korea Forest Service also introduced regulations to protect and minimize damage to forests by humans through restricting access to planted forests and developing fuel woodlots for rural people. As a result, more than one million hectares of forest were planted with fast-growing tree species like *Larix kaempferi*, *Pinus rigida*, and *Populus* sp. The 10-year project was completed in 6 years in advance with reforestation of 1.08 million ha achieving more than its planned target.

2.2 Second National Forest Plan

The Second National Forest Plan (1979-1987) was devised to establish large-scale commercial plantation forest for sustainable timber resources to meet domestic demand. The KFS introduced private forest development fund and expanded the national forests. Since then, various forest policies and regulatory instruments were devised and implemented by the Government in order to achieve forest rehabilitation, enhancement of forest protection, and foundation of forest development funds to support private and national forests. Along with the reforestation projects, erosion control was actively undertaken to prevent natural disasters, and advancement in the control of forest pests and diseases. Under the second national forest plan, 80 large-scale commercial forests were established bringing 325,000 ha under successful reforestation and a total of 1.06 million ha replanted (KFS, 2012b). Major reforestation tree species were; Italian hybrid poplar (25%), larch (18%), Korean pine (12%), hybrid aspen (7%) and, hybrid pine (1%) (Lee and Suh, 2005).

2.3 Third National Forest Plan

The Third National Forest Plan (1988-1997) aimed at establishment of multifunctional forests and harmonizing the economic functions and public benefits of forests. The plan focused on establishing the foundation and infrastructure for forest management including forest road construction, forest mechanization, education for foresters and forestry workers. The KFS also implemented forestry income enhancement projects for improving living standards of rural people and public awareness-raising programs highlighting the importance of forests and their conservation, established natural forest resorts increasing water supplies, and creating wildlife habitats. The KFS established commercial forest zones of 32,000 ha and conducted tending operation in over 3 million ha forests (Lee and Suh, 2005). To meet future industrial wood demand, the Government initiated overseas plantation projects in 1992 with the aim of securing stable and long-term timber supplies. To promote effective forest management practices, the Forest Law was amended and the Act on the Promotion of Forestry and Mountain Village was implemented in 1997.

2.4 Fourth National Forest Plan

The Fourth National Forest Plan (1998-2007) entered a transitional phase of forest policies with emphasis on economic functions, sustainable forest management including public and recreational benefits. The KFS put special emphasis on development of valuable forest resources and fostered competitive forest industry thereby increasing public benefits for the people. The Government-led forest management policies turned into automatic forest management policies in the private sector based on the capability and discretion of forest owners. To implement the sustainable forest management, the KFS consolidated legal and institutional frameworks through amendment of Framework Act on Forest, the Act on Promotion and Management of Forest Resources, the Act on the National Forest Management, the Act on Forest Culture and Recreation and, the Act on Promotion of Forestry and Mountain Villages in 1997. The plan also developed and implemented policies for improving public benefits of forests, including creation of network of recreation forests, water resources conservation, and wildlife protection. The KFS recommended 78 tree species for planting, which included 23 timber species; *Pinus densiflora*, *Pinus koraiensis* and *Larix kaempferi*; nut tree species; *Castanea crenata*, *Juglans sinensis*, and; 51 special purpose tree species with specific uses such as medicinal, pollution control, shade tolerant and fire-resistant (Lee and Suh, 2005).

2.5 Fifth National Forest Plan

It can be clearly seen that forest policies and regulatory frameworks have evolved from forest reforestation in 1973 focusing on restoration of denuded forest land with more or less single species to achieving the multiple values from multiple functions of forests. Throughout, the progressive National Forest Plans, forest landscape restoration has been the overriding objective and public participation, the cornerstones to making forest restoration a success and placed forest for the welfare of the societies. Based on the foundation frameworks established under the previous plans, the Fifth National Forest Plan (2008-2017) aims to consolidate and strengthen the implementation of sustainable forest management in pursuit of maximizing forest functions and values for the benefits of public at large.

The overall vision of the Fifth National Forest Plan is “to realize a green nation with sustainable welfare and growth” by sustainably managing forests as key resources for strengthening the nation’s economic development, land conservation and an improved quality of human life. The vision clearly encapsulates the new role of forests in carbon sequestration to combat climate change, foster socio-economic development placing strong emphasis on the recreational and cultural value of the nation’s forests to the public. To achieve the far-sighted vision: the KFS strategizes establishment of integrated framework for conserving and using forest ecosystem and biological resources; management of forest land and control of forest disasters prevention; establishment of system for expanding and maximizing public benefits from forests; sustainable forest resources management system; forest carbon management system; forest-based industries for vitalizing forest-related industries and; establishment of overseas plantation forests for global environment conservation. The new paradigm for forest use expands to forest for public health including therapy and recreation forests, “from cradle to grave” forests and development of timber resources and carbon sinks through overseas plantation projects.

2.6 Achievement of forest landscape restoration

As a result of continued forest landscape restoration under the various plans and guided by the noble policies of the Government and forest-friendly public participation, ROK has now an astounding forest cover of 64.1% (6,421,639 ha) of 10,018,808 ha of the total land surface area (KFS, 2013). The forest cover target matches with the 64% of the nation's total land surface area under mountainous terrains (Kim et al., 2007) which is ecologically important for sustainable development of mountain societies. Not only the forest cover has been increased but also the growing stocks increased from 9.6 m^3/ha in 1960 to 125.6 m^3/ha in 2010 (Figure 2) with a total growing stock of 64 million cubic meters to 800 million cubic meters, respectively (KFS, 2012b). Besides goods, the benefits of forests to public primarily through production of ecosystem services are immense. According to KFS in 2010, public benefits from ecosystem services are estimated at 107.52 billion United States (US) dollars. Out of the total, drought and flood prevention accounts for US $ 19.9 billion, erosion control and landslide prevention (US $ 20.7 billion), water quality improvement (US $ 6.4 billion), air quality improvement (US $ 22.3 billion), forest recreation (US $ 16.1 billion), landscape improvement (US $ 15 billion), and wildlife protection (US $ 7.6 billion). According to Global Partnership on Forest Landscape Restoration (GPFLR), the Republic of Korea estimates a 50 fold return on its investment that improved and restored forests over 50% of its territory since 1953 (Saint-Laurent, 2011).

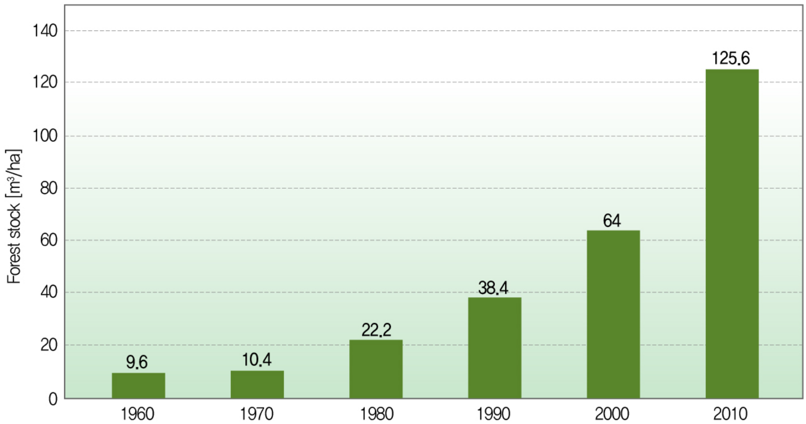

Figure 2. National forest stocking from 1960-2010 (KFS, 2012b)

KOREA FOREST RESEARCH INSTITUTE

3. Drivers and challenges of forest landscape restoration

3.1 Anthropogenic drivers of forest landscape change

Korean forests have suffered from human activities and natural events since the Chosun Dynasty from 1392-1886. According to Lee and Suh (2005), under the Chosun Dynasty, pine forests were protected for a long period of time. Later, the dynasty promulgated a forest control system that removed the provisions of Shiji (land for collecting fuelwood) and Gumsan system which regulated forests for a specific national use such as providing coffins for the royal family (Park, 1998b). In the 19th century, the forests were extensive with primary old-growth characteristic however, during the Japanese occupation period (1910-1945), forests were severely destroyed due to overharvesting and illegal cutting for fuel and building materials followed by Korean War (1950-1953). During the post-Korean war period, the harvesting of forests for fuel continued due to shortage of domestic cooking and heating energy. In 1960, there were about 2.4 million households in the country, each requiring about 0.5 ha of forest to meet the fuel demand (Lee and Suh, 2005). One of the priority of the then Government was to establish fuel wood plantation, which could meet the demand and concomitantly reforest war devastated forests. Lee and Suh (2005) summarizes the greatest achievements of the forest landscape restoration as “the first functional improvements of ROK environment have already appeared such as erosion control, improvement of soil quality and increasing biodiversity conservation." Nevertheless, the full effects of forest landscape restoration will not be seen for at least another 50 years. Increasingly, forest landscape restoration policy has shifted from an emphasis on exotic plantation species towards native species and mixed natural and artificial regeneration to realize the development outcomes of biodiversity and sustainable forest management. In order to achieve these development outcomes, new kind of challenges surrounds forest landscape restoration in the ROK.

3.1.1 Forest fires

The ROK experienced the biggest fire in the spring of 1996 followed by six times forest fires in 2000 burning about 24,000 ha of forest (Lim and Kwon, 2013). The 1996 forest fire brought about social debate between traditional foresters who insisted on traditional post-fire restoration by artificial regeneration and environmentalists who insisted on natural regeneration of the post fire burnt areas. Since then, forest fires continue to constitute as one of the important human disturbances not only burning trees but also insects and wild animals that play a crucial role in forest ecosystem restoration process. Shin (2007) reported forest fire occurrence on an average of 543 cases and 1,844 ha of forest damaged per annum. The recent forest fire statistics by Won (2013) show an average of 387 fires burning 734 ha of forests annually. Small scale undetected fires account for more than 2,500 incidences. However, data from 2008-2012 revealed an average number of

343 fires incidences and 613 ha of forest burnt annually (KFS, 2012a). Although there is decrease in the number of forest fire occurrences and forest burnt, there is considerable variation from year to year. The number of forest fires was the highest (570 fires) during 2009 and then decreased to minimum (198 fires) in 2012 (Figure 3) due to timely intervention and operationalization of forest fire prevention and control mechanisms. Forest fire frequencies are increasingly related to increase in temperature possibly due to climate change. The increase in temperature and decrease in humidity, rainfall and precipitation days have triggered forest fires in Yeongnam, Honam and Chungcheong (Choi, 2010a). Most forest fires are caused by human carelessness. Won (2013) identified the causes of forest fires as; 42% by mountain hikers, 18% by land clearing, 10% by waste incineration, 9% by cigarette smokers, 6% by cemetery visitors, 2% each by children and construction workers and, 11% by other activities.

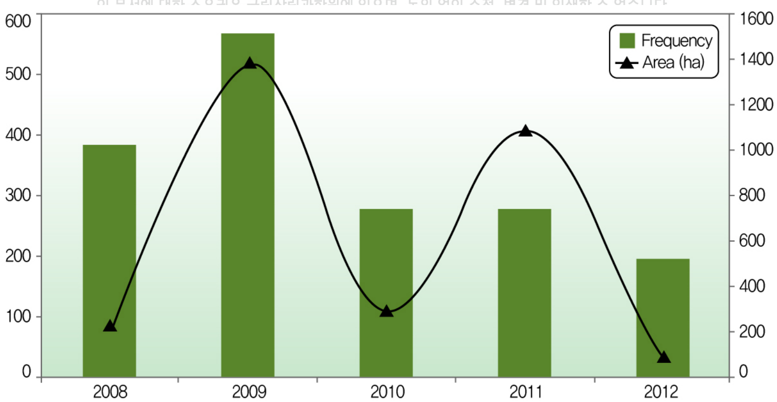

Figure 3. Frequency of forest fires and area burnt

Forest fires prone months are from November to May. However, most forest fires occur from March to May during which rainfall is minimum and experience strong seasonal winds orchestrated by dynamic local weather condition. Forest fires continue to burn hundreds of hectares of forests. At times, the active suppression of forest fires lead to accumulation of fuel loads in forest floor, which has consequences on fire regimes from frequent small fires to less frequent large forest fires aggravated by climate variability and climate change (Park, 2013). Thus, it can be generally deduced that forest fires continue to be one of the major threats to successful forest landscape restoration.

Figure 4. Forest fire burnt trees at Uljin (KFRI archive)

3.1.2 Conversion of forest land to non-forest land

Although on a smaller scale than forest fires, conversion of forest land to non-forest purposes such as agricultural land (farming and grassland, residential, factories, roads, golf courses, ski slopes and burial grounds) do take place. According to Kim (2013) due to rapid economic growth of ROK, forest landscape fragmentation has increased with consequences on loss of biodiversity in terms of decrease rural-urban interface forests, connectivity function of forests and creation of forest edges. The conversion of forest land to non-forest purposes trends from 2007-2012 is given in the Figure 4. The conversion of forest land to agricultural and residential land has remain more or less constant over the period of years and forest land conversion for ski slopes, factories, golf courses and roads show a declining trend, which indicates less forest land being converted for such purposes. The trend illustrated (Figure 5) shows only complete conversion of forest land to non-forest purposes and does not include forest land that are in the process of conversion (semi-conversion forests) and mining purpose. Forest land mining has been classified as temporary land use since 2010 in accordance with the revised provisions of the Act on Management of Mountainous Districts.

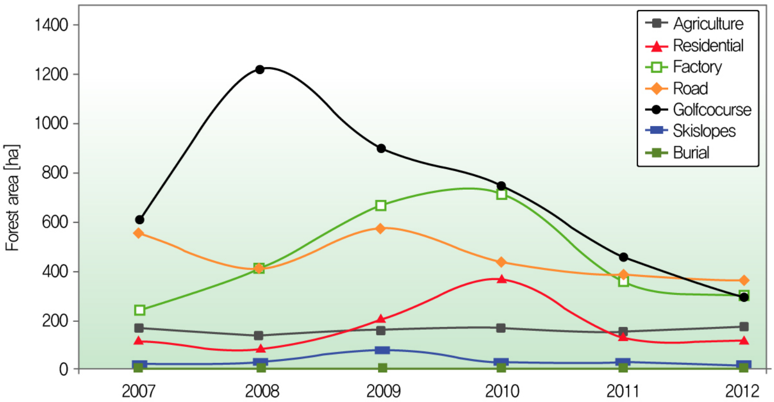

Figure 5. Conversion of forest land to complete non-forest land

3.1.3 Forest fragmentation by mines and stone quarries

Though mining is classified as a temporary land use, past exploration and operation of mines, and stone quarries in the ROK highlands have fragmented forest landscapes. The consequences are visible in many areas (Figure 6 & 7), which pose a minor challenge in the reforestation of abandoned mine waste soil heaps and stone quarries. According to the statistical yearbook of forestry 2013, the number of mines in 2010 decreased to 55 mines from 161 mines in 2009 and 90 mines in 2008 (KFS, 2013). Because 60% of coal mines go as wastes, dumping of waste mine soil nearby forest ecosystem led to loss of forest and acidification of forest soil. Besides, the forest scenic beauty is lost and leaves behind a scar in the face of landscape for a long period of time.

Figure 6. Past mine operation at Gangneung (KFRI archive)

Figure 7. Past stone quarries, Baekdu-Daegan (KFRI archive)

3.1.4 Forest pests and diseases

Insect pests and diseases are continuous threat to forest landscapes and are being monitored since 1960s. Because of the cultural value of pine trees in Korea, pests of pine forests such as pine moth, pine needle gall midge, black pine blast scale, and pine wilt disease have been intensively studied. The composition and dynamics of these pests are clear examples that show relationships between changes in forest landscapes and forest pests (Shin, 2007). According to Choi (2012), the major forest diseases and the areas affected from 1975-2000 (Figure 8) and 2001-2012 (KFS, 2006-2013) are given in the Figure 9 below. While the areas affected have been decreasing from 1975-2000, however, pine needle gall midge affected areas increased from 2005-2008 (Figure 9). Forest pests and diseases threat increases due to single species forests and global warming leading to change in flora, fauna and microbial organism and introduction of invasive species through increase in international trade (Choi and Park, 2012). The occurrence of major pests and diseases and their implication on forest landscape restoration are briefly described below.

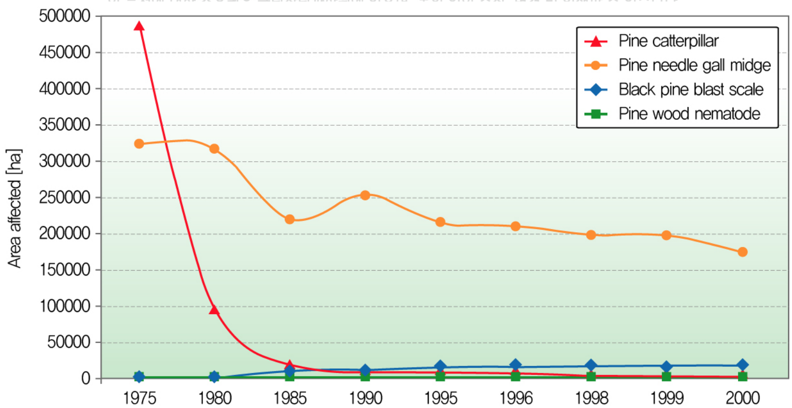

Figure 8. Major forest diseases and areas affected (Choi, 2012)

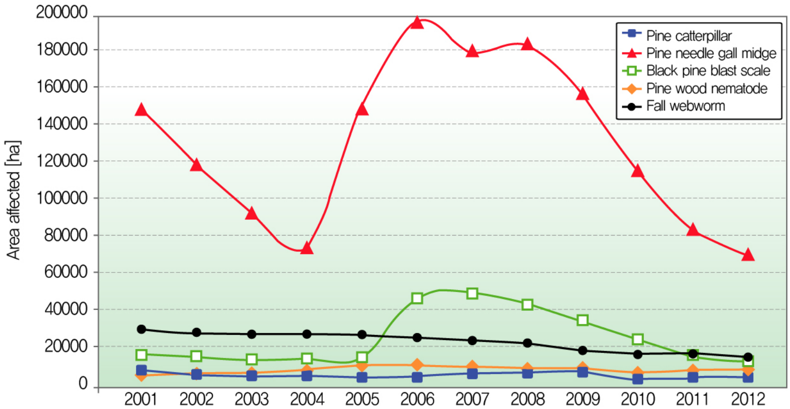

Figure 9. Major forest diseases and areas affected (KFS, 2006-2013)

3.1.4.1 Pine needle gall midge

The pine needle gall midge (*Thecodiplosis japonensis*) is a major forest insect pest in ROK causing significant damages on *Pinus densiflora* and *P. thunbergii* (Choi and Park, 2012).

Its first occurrence was reported in Seoul and Mokpo in 1929; Busan in 1934, Danyang in 1964 (Park et al., 1985). The pine needle gall midge occupied more than 80% of ROK in 1984 except some areas in Jeju Island (Lee et al., 1997). The area damaged by pine needle gall midge was 342,546 ha in 1979 but gradually decreased to 73, 206 ha in 2004 (KFS, 2006). After that the damaged area has fluctuated from year to year. The control cost increased exponentially from 1975 to US $ 34,000,000 in 1997 and then rapidly decreased (Choi and Park, 2012).

3.1.4.2 Black pine blast scale

Black pine blast scale (*Matsucoccus thunbergianae*) has caused severe damages to Japanese black pine (*Pinus thunbergii*) in ROK since 1963. Its first occurrence was reported in Goheung, Jellanam-Do, on the south western coast of ROK (Miller and Park, 1987). They suggested its origin from Kyushu, Japan. It is also postulated that the black pine blast scale is endemic to ROK; however, its occurrence pattern is typical to invasive species. The area damaged was 3,759 ha in 1983 but increased to 16,007 ha in 1996 and then gradually decreased to 11,988 ha in 2005 indicating that the black pine blast scale reaching its saturation phase (KFS, 2006). The control costs vary by the area damages accounting US $ 14,64,000 in 2005 (Choi and Park, 2012).

3.1.4.3 Fall webworm

The fall webworm (*Hyphantria cunea*) defoliates deciduous trees mostly. The introduction of fall webworm was reported in Seoul in 1958 (Chung et al., 1987). It was considered to originate from United States Army base at Itaewon in Seoul. Its distribution was limited exclusively to North America before 1940 but distributed to central Europe and eastern Asia during 1940s (Gomi, 2007). After the first detection of fall webworm in Seoul, it dispersed to almost half of the ROK by 1968 and entire country by 1972 (Choi and Park, 2012). The forest area damaged by fall webworm has gradually decreased from 52,653 ha in 1980 to 25,500 ha (KFS, 2006) and the population has been on the decline.

3.1.4.4 Pine wilt disease

Pine wilt disease is caused by pinewood nematode (*Bursaphelenchus xylophilus*) one of the major invasive pests in pine forests in ROK, Japan, China and Portugal (Togashi and Shigesada, 2006). It is native to North America and introduced in ROK at Mt. Geumjong in Busan in 1988 (Choi, 2012); Jinju, Haman and Tongyeong in 1999; Mokpo, Jellanam-Do, Gumi and Gyeongbuk-Do in 2001; Shinan, Yeongam, Chilgok near Gumi in 2003; Pohang, Gyeongju, Andong, Gyongsan, and Youngcheon in Gyeongsanbuk-Do in 2004/5; Jeju Island in 2004; Gangneung and Donghae in Gangwon-Do in 2005; Seoul, Gwangju, Namyangju, Pocheon, Wonju, and Chuncheon in the northeastern part in 2006/7; Youngdeok, Gyeongsanbuk-Do, Okcheon and Damyang, Chungcheongbuk-Do in 2009. By 2010, 67 areas had experience infestation. Its major host trees are; *Pinus densiflora*, *P.thunbergii* and *P. koraiensis*. The introduced pine nematode reproduces rapidly in the sap wood resulting in extensive tree mortality. Symptoms are occasional resin oozing out, discoloration of pine needle and die-back of shoots. The host plants die after 3 months of infection if environmental conditions are conducive to the disease proliferation. It causes significant economic, aesthetic and cultural loss of the forest. According to Choi and Park (2012), the area damaged was 72 ha in 1988 and less than 7,811 ha until 1999 (KFS, 2006) (see also figure 10 for trees effected and cut). The cost of control exponentially increased from 2000 and incurred US $ 29,000,000 in 2005 (Choi and Park, 2012).

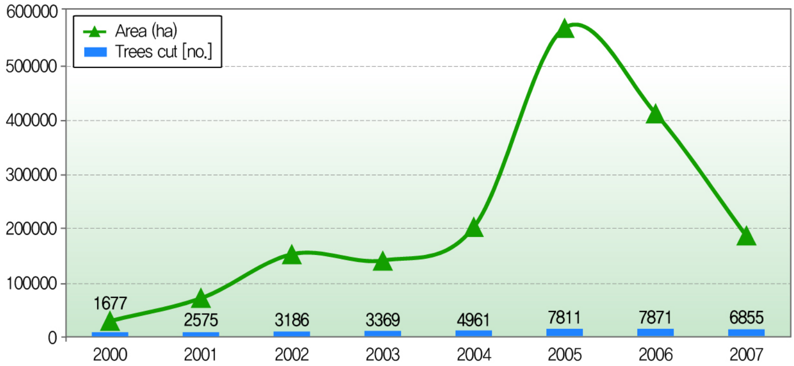

Figure 10. Area and number of affected trees by pine wilt (Choi, 2012)

3.1.4.5 Oak wilt disease

The first occurrence of oak wilt disease caused by Raffaelea fungus in ROK was reported in 2004 (Choi, 2012). The cause of oak wilt disease is known as a fungus of *Raffaelea sp.* and ambrosia beetle (*Platypus koryoensis*) as a vector of the fungus (Choi, 2012). The vector is distributed in Korea, China and Russia. The disease is considered as a hazard agent to oak and chestnut forest landscapes in Korea. Unfortunately, reason for the outbreak of the bark beetle is unclear. The infected oak trees were cut and fumigated to reduce density of the bark beetles. In addition, new control methods are under development.

3.2 Transboundary air pollution

The North East Asian countries of China, Mongolia, Japan and Korea constitute ¼ of the world population and consume about 13% of the world's timber production (Lee and Suh, 2005). These countries share many environmental problems that transcend national boundaries. In Mongolia, a large part of the semi-arid land has been degraded and denuded of forests caused by anthropogenic activities such as excessive grazing, logging and excessive use of water resources (Choi, 2010c). Mongolia has a desert area of 122 million ha (78.2% of the country) while China has 262 million ha desert area (27.3% of the country) (Choi, 2010c).

Deforestation and desertification lead to soil surface erosion by wind in central China and Mongolia generating dust storm popularly known as "Asian dust" which is blown over ROK and Japan early spring causing significant health problem and reduction in the agricultural productivity (Choi, 2010b). There is rapid increase of dust storm surge after 2000 in the ROK and Japan necessitating the control through large scale reforestation and sand dune fixation investment projects. In the Democratic People's Republic of Korea (DPRK), 20% of the forests are degraded and destroyed by human activities triggering flash floods with consequences on forest land degradation and desertification resulting in famine of the human population.

3.3 Climate change and climate change-induced natural disasters

According to Chun (2013), the mean annual maximum temperature has increased by 1.5°C in the 100 years (1910-2000) in the ROK, which is double the global average. Similarly, the mean annual precipitation increased by 10% in 100 years with higher precipitation (18%) in summer. The consequences of increased temperature and precipitation on forests are; change in forest areas, increased drought triggering forest fires, and increased risk of landslides and flash floods (Shin, 2007; Figure 11 & 12). Climate change is projected to alter ecosystem and ecosystem dynamics as well. The dangerous consequences of climate change are; change in landscape leading to loss of habitat for wildlife, and increased frequency and risk of natural disasters resulting in loss of human lives and property. The vegetation zones are projected to shift especially in high mountains. The sub-boreal and montane forest is highly vulnerable to the warmer climate. Using the scenario of climatic warming 2°C by 2100, shifts of potential ranges of several native trees including *Camellia japonica,* an evergreen broadleaf, *Quercus mongolica* and *Abies nephrolepis* were predicted based on thermal ranges of the species (Lim and Shin, 2005). The predicted changes of distribution ranges were dramatically shifted northward. Distribution ranges of the trees in the warm temperate forest zone, e.g., *Camellia japonica* were predicted to expand about two times, and 100 m high in elevation (Lim and Shin, 2005). Trees of cool-temperate forest and sub-alpine forest zones were predicted to become confined to half of the current ranges. According to Sung and Kim (2013), the health of the forest ecosystem is increasingly under threat exacerbated by global warming triggering wild forest fires, emergence of unforeseen insect pests and diseases, and soil acidification.

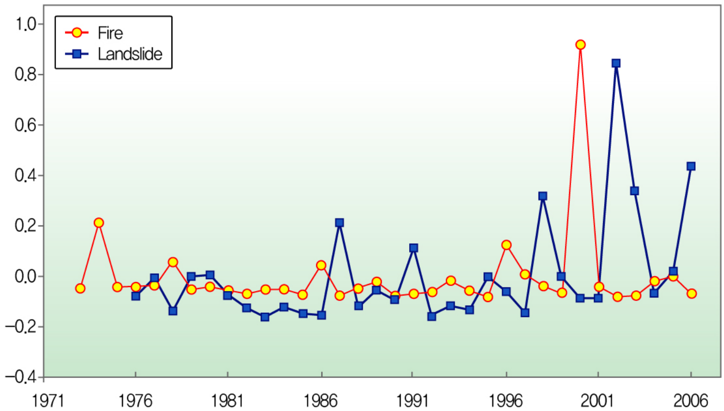

Figure 11. Changes in forest area disturbed by landslides and fires (Shin, 2007)

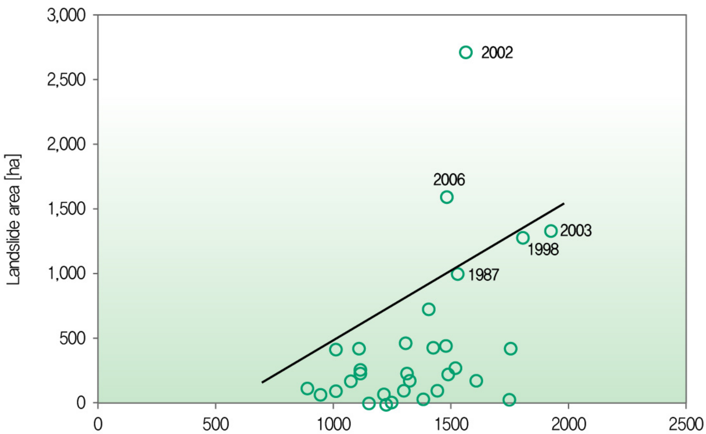

Figure 12. Relationship between landslides and precipitation (Shin, 2007)

The frequency and magnitude of natural disasters such as landslides and forest fires due to extreme weather events are increasing in the ROK. According to Choi (2010), the number of landslide occurrences has increased to 712 ha/year in 2000s from 289 ha/year in 1970s. The impact of natural disasters may be higher when extreme weather events strike particularly vulnerable areas.

KOREA FOREST RESEARCH INSTITUTE

4. Review of forest landscape restoration research in priority areas

4.1 Forest restoration in degraded landscapes

According to Lee and Suh (2005), the legacy of exploitation of forest resources during the Japanese invasion and subsequent Korean War continued during the 20th century. Political and social disorder, fuel shortage, continuous illegal harvest, and economic down-turn contributed to the large-scale devastation of forest resources. As a result, native tree species were overexploited leading to disappearance and leaving behind only dwarfed pines. Shifting cultivation among man-made disturbances has a very long history since the Shilla dynasty (Lee, 2002). The Korean War, illegal logging, and shifting cultivation (slash and burn agriculture) practiced in the mountainous region of ROK caused vegetation degradation, soil erosion and floods (Bae et al., 2012). Therefore, the ROK started projects for rehabilitation of shifting cultivation areas and denuded forests from 1960s - 1970s (Ho, 1975; Lee et al., 1979; Lee, 1995). Gangwon-Do with extensive shifting cultivation was the first province where greening project for shifting cultivation started. According to Lee and Suh (2005), pushed by the central Government following a presidential visit in 1971, erosion control projects and activities were implemented in 1973. About 50 small-scale erosion control projects were implemented since the 1950s. The areas of the erosion control projects in Yeongil extended from 129°5' to 129°26' E and from 35°54' to 36°16'N which included Yeongil, Weolseong-gun (county) and Pohang-si (city) and a five year erosion control project began in 1973. General erosion control measures were implemented in 3,291 ha, special erosion control measures in 479 ha and reforestation in 768 ha of denuded land totaling about 4,538 ha. Four erosion control techniques were used on gentle slopes. The techniques include; sod-patching channels to stabilize small valleys and safety discharge rain water; terrace soding structures to control rill erosion on slopes (Figure 13); contour trench to improve water holding capacity and promote vegetation growth and; underground structures (Lee and Suh, 2005). Steep slopes require more use of stones due to high water flow velocities. The five techniques used included; stone-patching channels, stone soil arresting structures to protect slopes from rill erosion, stone terracing structures to control overland flow and provide a stable surface to establish trees, latticed block works to control slope failure, and mulching structures to cover eroded structures. Valleys in the upper slopes or upland required the use of revetments to stabilize foot slopes in order to protect steep slopes; erosion check dams to stabilize foot slopes and control horizontal and vertical erosion and; erosion control dams to decrease stem run distances.

Figure 13. Contour terracing and planting for erosion control (KFS archive)

Trees and grasses were planted and seeded to stabilize soil surfaces. The direct seeding with over 20 kg seeds/ha of *Robinia pseudoacacia*, *Lespedeza bicolour* and *Cyperaceae sp.* were used. The mixtures were; half grass and a quarter each of *Robinia pseudoacacia*, and *Lespedeza bicolour*. Height growth after 1 year of planting was assessed; 80-90 cm for grasses, 150 cm for *Robinia pseudoacacia* and, 70-100 cm for *Lespedeza bicolour*. Two years after planting, *Robinia pseudoacacia* occupied the overstory. Other techniques include; planting of nurse trees (*Alnus sp.* and *Robinia pseudoacacia*) to supplement nitrogen fixing as fertilization on acidic soils and pioneer species such as *Pinus thunbergii* and *P. rigida* for coastal area and grassland reforestation. The project cost incurred US $ 3.19 million for labour intensive works mostly (Lee and Suh, 2005).

A systematic, planned and coordinated forest rehabilitation process was undertaken to address technical and institutional constraints (Figure 14).

The technical challenges to forest rehabilitation were; lack of basic information and data on seeds, species, soils and forest nurseries to provide planting size seedlings for the large-scale reforestation projects (Figure 14). In order to address these constraints, survey of national and private forests were done from 1960 - 1964 wherein mapping and identification of forest types, age class and tree species were done. Forest resources survey was conducted from 1964 - 1971, watershed soil survey from 1968 - 1969, forest soil survey from 1968 - 1973 and identification of forest land use category in 1967 - 1969. The situation was aggravated by poor seed sources and a few seedling production nurseries. To address the problem of poor seedling quality, Tree Breeding Research Institute was established to study and identify suitable trees species, conduct tree breeding research, which included establishment of seed orchards and designation of seed stands and mechanization of seedling breeding and development of nursery clusters and networking in the country. In order to prevent rampant slash and burn cultivation, which was environmentally destructive, 86,073 ha of the slash and burn area were brought under reforestation and reduced the migration of rural population to urban areas. To address the nation-wide shortage of fuel wood crisis, 640,000 ha wood fuel plantations were established substituting wood fuel by coal briquettes for heating and cooking purpose. To address the problem of poor law enforcement, governance, lack of technology, funding and human resources, the Korea Forest Service (KFS) was institutionalized.

Strong law enforcement was put in place by transferring forest sector tasks and authorities to the Ministry of Home Affairs. To address the technology gap and strengthen the research and development mandate of Tree Breeding Research Institute, active collaboration was pursued with Germany in the framework of Korea-Germany Forest Management Program. To address the funding constraints, collaboration with multilateral and bilateral international agencies (United Nations Development Programme (UNDP), Food and Agriculture Organization of the United Nations (FAO), World Food Programme (WFP), International Bank for Reconstruction and Development (IBRD) were pursued.

Approach to Forest Landscape Restoration in the ROK (KFS, 2012b)

Lack of basic information [soil, seeds, species, & nurseries] ➡	Forest Resources and Forest Soil survey [Mapping forest area, identification of land quality and soil types]
Lack of technology, funds and human resources ➡	Development of National Forest Plans 1^{st} National Forest Plan [1973-1982] [Plantation of fast-growing species for soil stabilization] 2^{nd} National Forest Plan [1979-1988] [Plantation of slow growing species for resource development]
Poor seed sources and seedling production ➡	Seed and Seedling Production [Establishment of seed orchards (710ha); seed stands (10 species, 184 sites); mass propagation of planting stock including quality and size]
Fuewood constraint nation-wide & slash and burn ➡	Fuel wood plantation [643,000 ha fuel wood plantation] Reforestation [12 billion trees on 2.1 million ha planted] [86073 ha of 124,643 ha slash and burn planted] Erosion Control Projects [Erosion control on 120,000 ha slopes/coastal areas] [Torrent erosion control on 5370 km]
Poor law enforcement & governance ➡	Maintenance and Law enforcement [Illegal logging, forest fire, forest diseases & pests]
Integrated plan for forest restoration ➡	Sustainable Forest Management [Forest Resource Development]

Figure 14. Approach to reforestation in the ROK

According to Lee and Suh (2005), the ecological effect of rehabilitation and erosion control in Yeongil was assessed in 1995. Soil depth (A and B horizon) of the hilly areas have increased from 1 - 2 cm in 1971 to 11 cm in 1995. Soil depth varied with 4 cm at the upper slopes and 112 cm at the lower valley slopes more than in the beginning of the program 24 years ago. The surface soil at the upper slopes remained shallow, which impeded root development of trees except at the base of the lower slopes. Soil texture changed from sandy loam to fine sandy silt loam with increased clay ratio and soil acidity (pH) reduced from 4.1 - 4.5 to 4.6 - 5.5. Root system development, rain interception and wind break effect by over story trees contributed to stabilizing the surface soils. *Pinus thunbergii* and *P. densiflora* were naturally regenerated as over story trees but with low density (5 - 20 trees/ha). To form the middle and bottom story, virtually lacking trees, seedling plantation were carried out. The understory trees grew well due to improved microclimate in the last 5 years (Lee, 2001) and tree cover improved (Figure 15). Species that were almost extinct such as *Parus major* (great tit), *Phasianus colchicus* (pheasant), *Streptopelia sp.* (Dove), *Sus scrofa* (wild boar), *Lepus brachyurus* (hare) and *Capreolus capreolus* (Roe deer) re-appeared. Harvesting and income generation from non-wood forest products increased.

(A) Denuded land in 1984

(B) Immediately after rehabilitation

(C) 5 months after rehabilitation

(D) Reforestation in 2005

Figure 15. Denuded forest land in 1984 (A), after reforestation (B) & (C) and in 2005 (D). (KFRI archive)

(A) Before reforestation

(B) After reforestation

Figure 16. Before and after reforestation (KFRI archive)

Because ROK needed to quickly bring the denuded forest land under vegetation (Figure 16) to control erosion and produce and supply fuelwood, early forest planning concentrated on fast-growing exotic species. As much as 70% of the total forest areas were under plantation. The main species planted were; *Robinia pseudoacacia*, *Pinus rigida*, *Alnus sp.* and *Quercus sp.* (Table 2). The choice of species from 1970s to 1980s shifted to *Larix kaempferi, Populus euramericana* and *Pinus koraiensis* in order to increase the commercial value of the forest resources (Table 2). The reforestation policy of fast-growing and single species plantation lead to simplified forest structure and low biodiversity, which in turn resulted in low stability and productivity. Recently, the policy has shifted to restoration that emphasized native species. In the ROK, species such as *Pinus densiflora* and *Quercus sp.* regenerate naturally in plantations and future restoration is likely to rely on native species.

Native species plantation is demonstrated in Gyeonggi-Do and Gangwon-Do province. Two study sites were established in Seongnam-si (37°70'N, 127°20'E), Gyeonggi-Do and in Yangyang-gun (38°05'N, 128°35'E), Gangwon-Do. The Gyeonggi-Do site in Seongnam-si near Seoul was planted in 1970s with *Pinus rigida*, *Robinia pseudoacacia* and *Alnus sp.* This site was disturbed by human activities and had a secondary forest with simplified forest structure. The study site in Gangwon-Do is located in the experimental forests at the Forest Works Training Centre in Yangyang-gun close to the east sea. The district produces pine mushrooms. Ecological restoration studies at Gyeonggi-Do revealed that the site was dominated by *Pinus densiflora* and *Quercus sp.* in 1960s. After destruction of the sites 30 years ago, *P. rigida*, *R. pseudoacacia* and *Alnus sp.* were planted for restoration. *P. rigida* plantation was done mostly with a few stands mixed with *R. pseudoacacia* and *Alnus sp.* for improving soil quality (Lee and Park, 1999). Apparently *P. rigida* grew quickly with good survival and seemingly adapted well but slowly faced increasing competition from *Quercus sp.* With no active management of the plantation sites for 30 years, *P. rigida* has been completely replaced by *Quercus accutissima* through natural ecological succession process (Table 3).

Table 2. List of native, exotic, hybrid and nut trees planted during reforestation from 1962-1992 (KFS, 1993; Lee and Suh, 2005)

Species/hybrids Native species	1962-1972 Area (ha)	1973-1992 Area (ha)
Pinus densiflora	14,902	17,050
Pinus thunbergii	68,121	30,254
Pinus koraiensis	53,333	277,031
Paulownia coreana	2,350	31,865
Rhus verniciflua	4,404	141
Quercus acutissima	26,077	6,273
Exotic and hybrids		
Pinus rigida	417,462	211,494
Pinus taeda	6,351	4,262
Pinus rigida x Pinus taeda	10,486	27,708
Larix kaempferi	265,773	393,306
Cryptomeria japonica	35,421	53,486
Chamaecyparis obtusa	32,745	81,226
Robinia pseudoacacia	414,690	111,083
Alnus species	124,027	160,521
Populus euramericana	153,710	551,565

Species/hybrids Native species	1962-1972 Area (ha)	1973-1992 Area (ha)
Poplus alba x p. glandulosa	-	142,438
Poplu nigra x p. maximowiczii	-	151,450
Nut trees		
Castanea crenulata	235,898	151,470
Juglans sinensis	4,890	4,575
Ginkgo biloba	1,668	9,643
Zizyphus jujuba var. inermis	305	2,560
Diospyros kaki	3,313	3,075
Diospyros lotus	3,383	425
Others	23,054	267,947
Total	1,902,363	2,690,848

Table 3. Importance value of the major tree species in Pinus rigida plantation at Gyeonggi-Do (Lee and Suh, 2005)

Species	Trees (no/ha)	Basal area (m^2/ha)	Relative density (%)	Relative coverage (%)	Importance value (%)
Quercus accutissima	482	8.31	44.2	63.4	53.8
Robinia pseudoacacia	309	2.41	28.3	18.4	23.4
Pinus rigida	59	1.52	5.4	11.6	8.5
Alnus species	14	0.19	1.3	1.4	1.3
Others	227	0.69	20.8	5.2	13

For ecological restoration at Gangwon-Do, *Pinus koraiensis* plantation was established in 1973 after harvesting of the native *Pinus densiflora* stands. After 30 years, *Pinus densiflora* has grown naturally and faster in the area than *Pinus koraiensis*. Based on the results, *Pinus densiflora* is recommended for future planting for ecological and economic purpose of producing pine mushroom in the ROK (Cho and Lee, 1995; Koo and Bilek, 1998). *Larix kaempferi* is another timber species that grows well in moist and fertile sites in valleys but performs poorly in slopes and ridges.

Forest rehabilitation for the protection of the Baekdu-Daegan Mountain System (BDMS) was important for preservation of its economic, environmental, ecological, and aesthetic values (Kim et al., 2010). Development-oriented policies during the past decades have caused fragmentation and degradation of forests and transformation of BDMS landscapes. Accordingly, measures to protect the BDMS from over emphasis on development and to restore the degraded ecosystems were put in place. In 2004, the Korea Forest Service set the criteria for designating protected areas within the BDMS through a public hearing process. Finally, the Act on Protection of the Baekdu-Daegan Mountain System came into effect on January 1, 2005 and the BDMS declared as protected areas on September 9, 2005. A total of 263,427 ha (core zone: 169,950 ha, buffer zone: 93,477 ha) have been established. The management strategy of the BDMS protected areas was put in place. Soil eroded road slopes were rehabilitated using various degraded land restoration techniques. In order to restore the uphill cut slopes of the forest road, steep slopes (plot 1, A) and gentle slopes (plot 2, B) were selected (Figure 17). The steep and gentle slopes were nested with 5 treatments namely; coir net, native ground restoration (NGR), SDR (species diversity restoration), geo-fibre, and control (Figure 18).

(A) (B)

Figure 17. Forest road restoration in steep slopes (A) and gentle slopes (B) (KFRI archive)

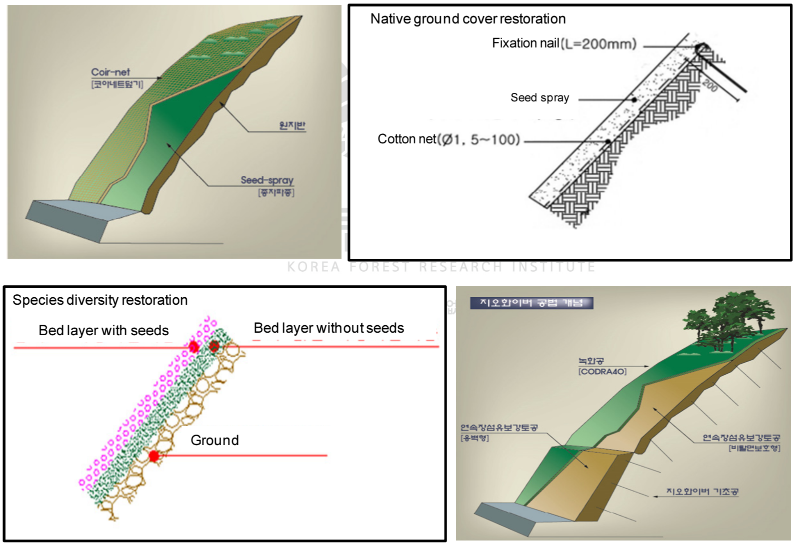

Figure 18. Four vegetation restoration techniques applied in steep and gentle slopes (KFRI archive)

(A)

(B)

(C)

(D)

(E)

Figure 19. Vegetation cover in successive years (A) before planting, (B) 3 months after planting, (C) 1 year, (D) 2 years and (E) 3 years after planting (KFRI archive)

Each treatment has an area of 100 m^2. Hydro-seeding treatment technique was applied to species after making soil bed at 0.4 cm (coir-net), 3 cm (native ground cover restoration), 10cm (species diversity restoration, its 2-layers seed spray), and 30 cm (geo-fibre) in depth (Kim et al., 2010). After the planting of vegetation, the visible impact of planting in the successive months and years was measured and photographed (Figure 19) showing successive vegetative cover leading to gradual restoration of the steep forest road slopes.

According to Kim et al (2010), three years later, vegetation coverage ratio in the respective treatment was as follows; geo-fibre has the highest cover (95%) with 12 survived species. The species were; *Albizia julibrissin, Lespedeza cyrtobotrya, Indigofera pseudoinctoria*; native grasses, *Lotus corniculatus* var. *japonica* and etc.,) and exotic species *(Artemisia princeps* var. *orientalis,* etc.). The SDR has 85% vegetation cover with survived plants (*Betula platyphylla* var. *japonica, Rhus chinensis* and, *Lespedeza cyrtobotrya*) and imported grasses including tall fescue, etc., invaded species (*Crysanthemum boreale*, etc). The NGR has 70% vegetation cover with tree species (*Albizia julibrissin, Rhus chinensis, Lespedeza cyrtobotrya*), native grasses (*Lotus corniculatus* var. *japonica,* etc) and exotic grasses (*Lespedeza cuneata*, etc). The coir-net had 5% cover ratio with tree species (*Lespedeza cyrtobotrya*), native grass species; *Artemisia princeps* var. *orientalis*, and exotic species (*Youngia sonchifolia*, etc). They concluded from the experiment that geo-fibre has good vegetative restoration potential with *Indigofera pseudotinctoria* as dominant species and SDR with tall fescue as dominant grass while coir-net had poor vegetative restoration.

The current erosion control projects from 2008-2012 focus on the erosion control of dams (3,744 sites), landslide prevention (224 ha), stream conservation (741 km), forest watershed management (57 sites) and to a lesser extent on coastal disaster prevention forest (54 ha), prevention of coastal erosion (23 km), and sediment reduction in multi-purpose dams (40 sites) (Table 4).

Table 4. Erosion control projects from 2008-2012 (KFS, 2013)

Year	Landslide prevention (ha)	Erosion control dam (sites)	Stream conservation (km)	Coastal disaster prevention forest (ha)	Prevention of coastal erosion (km)	Planted seedlings (x 1000)	Multi-purpose dams (sites)	Forest watershed Management (sites)
2008	37	442	51	9	3	276	1	9
2009	60	827	62	10	5	337	-	15
2010	37	807	65	12	5	192	15	15
2011	42	813	124	10	4	210	15	-
2012	48	855	439	13	6	281	9	18
Total	224	3,744	741	54	23	1,296	40	57

The 2008-2012 plantation species, area planted and seedling production are given in the Table 5. The Table 5 shows that the change in plantation species with emphasis on the native pines, *Pinus koraiensis*, *Larix kaempferi*, Japanese cypress (*Chamaecyparis obtusa*) and oriental chestnut oak (*Quercus acutissima*) with increasing area under plantation. Plantation species have focused on native species of pines and inclusion of more broadleaves compared to 1962-1992 period, which concentrated in the plantation of exotics.

Table 5. Current plantation species, area planted and seedling production (KFS, 2013)

Species	2008		2009		2010		2011		2012	
	Area (ha)	Seedling (x 1000)	Area (ha)	Seedling (x 1000)	Area (ha)	Seedling (x 1000)	Area (ha)	Seedling (x 1000)	Area (ha)	Seedling (x 1000)
Pines	3,914	9,169	3,853	8,303	5,107	10,532	4,456	9,955	4,865	10,979
Pinus koraiensis	1,935	4,779	1,575	3,515	1,482	3,740	1,408	3,338	1,759	4,588
Larix kaempferi	505	1,095	962	2,042	805	1,964	712	1,935	463	1,089
Japanese red cedar	31	120	18	51	24	71	6	17	43	15
Japanese cypress	1,622	3,887	1,656	3,785	1,495	3,845	1,449	3,490	1,872	3,979
Painted maple	232	473	140	237	207	317	91	222	110	193
Zelkove	566	1,301	434	1,057	398	931	343	878	205	558
Korean ash	215	647	62	181	273	601	199	265	42	126
Oriental cherry	4,349	8,159	3,978	6,164	432	554	515	602	410	446
Oriental chestnut oak	1,441	4,142	1,288	3,082	3,029	5,302	2,671	4,368	1,410	3,177
White birch	232	473	140	237	1,377	2,866	775	1,781	637	1,623
Total	15,042	34,245	14,106	28,654	14,809	30,723	12,625	26,851	1,1816	26,773

4.1.1 Forest restoration research strategies in degraded landscapes

The ROK is a mountainous country with high diversity of geology and soils. According to Jeong (2013), forest soil is classified into 8 groups, 11 soil sub-groups and 28 soil types. The major soil groups are; brown forest soil (B), red and yellow forest soil (R-Y), dark red forest soil (DR), gray brown forest soil (GrB), volcanic ash forest soil (Va), eroded soil (Er), immature soil (Im) and lithosol (Li). Eroded soils are characteristics of mountain ridges and convex slopes. They are formed as a process of erosion from well-developed soil horizons eroded by rainfall. The L and F layer are thinly deposited on the B or C layers. Horizon differentiation is not distinct and loose granular structured. The eroded soil is sub-classified into slightly eroded soil (Er_1), severely eroded soil (Er_2), and erosion eroded soil (Er-C). Slightly eroded soil is a soil whose A and some portion of B layer is eroded due to rain and deposited in the gentle or convex portion of mountain slopes. It is dark brown in colour, dry and loose granular in structure. The plant roots are distributed near the surface layer and B layer is without structure. The severely eroded soil is the soil that lost its B or C layer by erosion and found in steep mountain slopes. The erosion control soil is a soil that eroded severely in the past and layers have not been developed and have indistinct soil morphological feature. Forest landscape restoration by tree species and soil types is given in the Table 6.

According to Wilpert (2013), there are several anthropogenic threats for the function and diversity of forest soils, which impair forest health and growth. Unlike agriculture soils, forest soils cannot be conditioned in a short-term due to long-lived natural ecosystem and there are few options to manage forest soil chemical and physical properties. As a result, forest soils are very susceptible to man-made land use and environmental changes like acidification aggravated by climate change. Management options to combat the internal and external threats for the functionality and diversity of forest soils are needed. The options include but not limited to; forest liming where soil is acidic, wood ash recycling to compensate the loss of nutrients through biomass harvest, concentrating machine activities in a predefined forest trails and studying nutrient sustainability through nutrient budgets as a precondition for preserving soil diversity for restoring biodiversity.

Table 6. Recommended species for forest landscape restoration by soil type and use (KFRI, 2010b)

Soil type	Use	Recommended species
B_3	Commercial	*Quercus acutissima, Fraxinus rhynchophylla, Liriodendron tulipifera*
	Fruit	*Castanea crenata, Diospyros kaki,*
	Landscape, special	*Acer mono, Zelkova serrata, Acer triflorum, Cornus controversa, Prunus sargentii, Cornus kousa, Cornus officinalis, Albizia julibrissin, Maackia amurensis, Hovenia dulcis, Crataegus pinnatifida, Eleutherococcus sessiliflorus, Rhus verniciflura, Aralia elata, Ulmus davidiana, Lycium chinense, Zanthoxylum schinifolium, Cedrela sinensis*
B_2	Commercial	*Pinus densiflora, Quercus variabilis, Quercus acutissima*
	Fruit	*Castanea crenata*
	Landscape, special	*Zelkova serrata, Cornus kousa, Prunus sargentii,Cornus officinalis, Albizia julibrissin, Aralia elata, Maackia amurensis, Ulmus davidiana, Lycium chinense, Zanthoxylum schinifolium*
rB_1	Commercial	*Pinus densiflora, Quercus variabilis*
	Fruit	*Castanea crenata*
	Landscape, special	*Zelkova serrata, Cornus kousa, Prunus sargentii, Cornus officinalis, Albizia julibrissin, Aralia elata, Maackia amurensis, Zanthoxylum schinifolium, Lycium chinense*
DRb_2	Commercial	*Pinus densiflora, Quercus variabilis*
	Landscape, special	*Prunus sargentii, Aralia elata, Ulmus davidiana, Lycium chinense*
Others	Commercial	*Pinus densiflora, Quercus variabilis*

Hirai et al (2013) documents the recent threats of forest soil erosion in Japan due to single-species forest or plantation such as cypress. Other contributing factor includes excessive deer browsing, improper management of plantation stands mainly in the south-western region and severe soil disturbances by forestry machines. They found that susceptibility of forest soil erosion is dependent on the forest floor cover by litter or understory species. The evidence of soil erosion increases with slope % but decreases with floor cover percentage (FCP). FCP is a good indicator because it detects signs of soil erosion as a precautionary principle but varies with forest types. From the past restoration measures in degraded areas and review of similar literature from elsewhere, it can be concluded that:

- The erosion rate can be reduced by both artificial aligning and spreading of coarse woody debris (trees and branches) along the contours, which not only control erosion but also add nutrient budgets in the soil after decomposition (Figure 20).

Figure 20. Erosion control using woody branches (KFRI archive)

- FCP can be manipulated by forest management activities e.g., retention of tree branches and twigs spread on the forest floor can help reduce soil erosion during rainfalls. This should not be practiced in areas where there is an outbreak of pine wilt disease.
- Allow the single species plantation forests to develop natural recovery of understory and forest floor cover species over a period of time. Natural regeneration should be encouraged by protecting naturally regenerated succession from browsing herbivores and fires.
- Establish the reference forest ecosystem or "novel ecosystem" e.g., primary growth forests at Baekdu-Dagen as benchmark or reference sites on which the restoration is designed and will serve as basis for restoration project evaluation in the future.
- While native tree species should be preferred in restoration, exotic species should also be given due importance in some circumstances such as in degraded sites where native forest species take a long time to meet desired management objectives. Native tree species have superiority over exotic species in local circumstances. e.g., fire hardy, drought resistance, etc.
- Enrichment planting is an appropriate method in early succession sites lacking non-sprouting and pioneer tree species
- Local knowledge must be taken into account for the selection of tree species and local people consulted in the selection process.

4.2 Forest restoration in post fire-burnt areas

After a large-scale forest fire at Goseong occurred in 1996, many people were interested in the effect of forest fire on ecosystems and the method of restoration. A 100 ha Long-Term Ecological Research (LTER) was experimented at Goseong for the investigation of fire effects on ecosystems (soil erosion, water quality, vegetation, and wildlife). After the large East Coast Fire in 2000, about 4,000 ha of a new LTER site at Samcheok, Gangwon-Do, Korea was established. In this site, almost all kinds of research on forest ecology and silviculture were pursued; forest meteorology for examination of mountain climate, vegetation changes, insects, birds and small mammals, soil productivity, erosion control effects for reducing post-fire erosion, hydrological influence, characteristics of fire damage according to stand structure, and forest stand control for building of forest fire resistant species, etc. Sediment runoff was very severe in the first year after fire but reduced to natural levels in the third year. Water quality was restored in the year after the forest fire. Recovery of tree species was progressed by sprouting of *Quercus sp.,* and recovery of herbaceous perennials. The number of insect species increased at the beginning, but later decreased gradually. The number of bird species decreased after fire and increased in the limited number of bird species that live in grassland.

The East Coast Fire of April 2000, in which 24,000 ha of forest razed, brought social debate between traditional foresters who insisted on traditional post-fire restoration by artificial regeneration and environmentalists who insisted on natural regeneration. Conventional tree planting using exotics was criticized and experts and local organizations participated in the 5-year forest restoration plan of Korea Forest Service. The plan was established with a combination of natural regeneration and artificial planting technique i.e., 48.5% of fire damaged area would be restored by natural regeneration, and 51.5% would be artificially planted. Containerized seedlings of red pine were planted in the coastal and the inland mountain areas in the east coastal fire region (Figure 21). The emergency restoration, erosion control and restoration for pine mushroom (*Tricholoma matsutake*) were the main restoration objectives by 2001. The restoration strategy of the east coast fire damaged region was followed using the ecological and social decision-making process in consultation with land owners, and local Government authorities following these guidelines:

- Ecological restoration method should be followed.
- Combination of natural and artificial regeneration techniques
- Rapid restoration of landslide hazard area should be done
- Direct seeding or planting of containerized tree seedlings of red pine for pine mushroom
- (*Tricholoma matsutake*) restoration
- Natural restoration of areas where crown layer is alive, or habitats for specific animals or plants should be followed
- Restoration for scenic landscape beauty using the most appropriate restoration method
- Building of forest road should be based on environmentally-friendly policies and practice.

Post-fire restoration used natural or artificial methods depending on site condition and management objectives (Figure 22). Ahn et al (2014) highlighted the importance of understanding post-fire processes in forest ecosystems in order to implement ecologically sound post fire forest restoration practices. They found out that natural restoration after large fires depends on regeneration sources (e.g., seeds and sprouts) of the remaining trees that have sustained less damage, until secondary forest are established. However, severely burnt areas may require rapid artificial regeneration depending on the specific climatic (e.g., summer rainy season), geographic (e.g., shallow surface soil and land erosion) and economic (e.g., local mushroom harvesting) objectives. Not only efforts to restore fire damaged areas but also more efforts for prevention of forest fires were actively pursued. However, the decision making process vary with sites. In Yaesan forest fire during 2002, and Yangyang forest fire during 2005, respectively restoration plans considered fire severity (moderate or severe), slope characteristic, type of soil and number of sprouts and public consultation to arrive at decision-making followed by a combination of ecological and socio-economic restoration method (Figure 22).


(A)


(B)

Figure 21. Forest stand restoration after fire (A) burnt stand (B) post-fire plantation (KFRI archive)

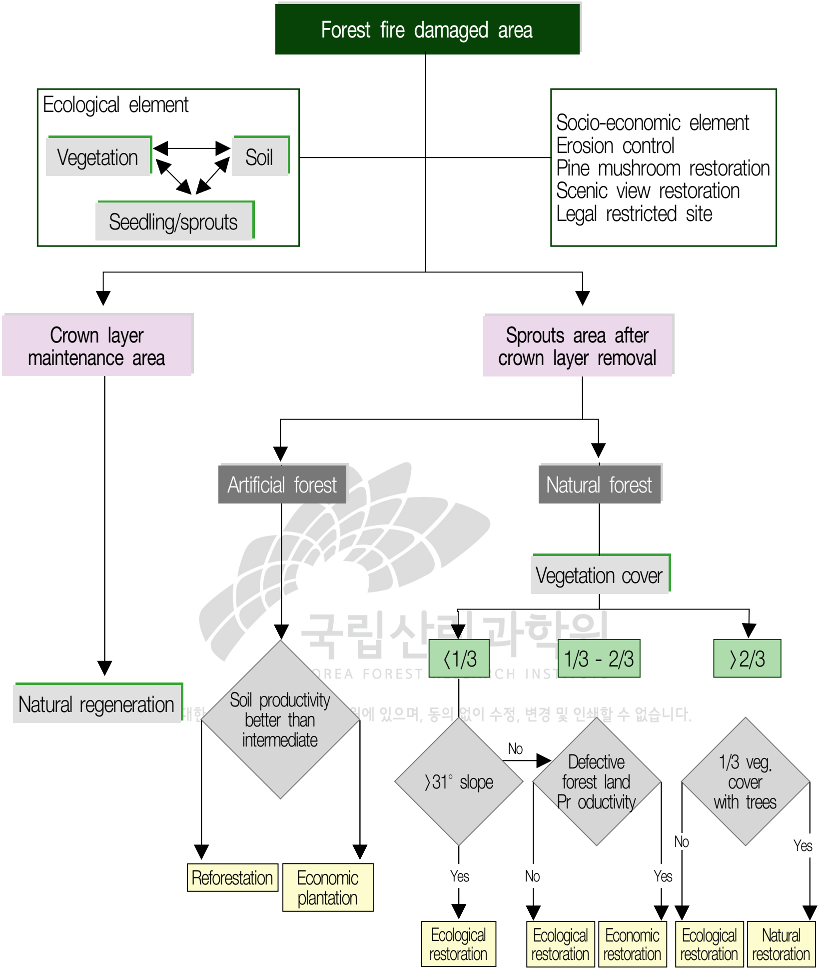

Figure 22. Post-fire restoration decision-making process (KFRI, 2010b)

According to Park (2013), forest fire research in the past (1900 - 1970s) dealt on wild land fire policy, preparedness, firefighting, fire weather, fire impact and fire statistics. From 1970s - 1980s, fire research agenda became more diverse and detailed with time. Fire research included; effects of fire on vegetation, regeneration of conifer forests, soil, nutrition, ash-fertilization, sediment and catchment. The effects of fire on wildlife were also included. Prescribed burning, fire history, fire danger, fire frequency and post-fire effects were actively researched. The fire modeling began in 1980s. Fire management was the central theme of the wild land fire research. Increasing anthropogenic activity such as forest land and forest conversion to non-forest purposes, monoculture, industrialization and globalization have changed wild land fire environment and fire regimes. As a result, large fires are occurring in areas where a few fires occurred in the past. Active fire suppression at times can lead to fuel accumulation in forests thereby making forests more vulnerable and susceptible to wild fires. From 1990 to present, fire research modeling progressed with the development of Remote Sensing and Geographic Information System (GIS) tools. The salient findings of current research on forest fires in the ROK and fire research studies grouped into fire ecology, effects on regeneration and stand growth and development, and restoration of conifer and broadleaves forests are summarized below.

Many studies on forest fires and natural and artificial regeneration of forests in ROK were conducted. A study on the effect of Jellyfish fertilizer on planted seedlings of *Pinus thunbergii* and *Quercus palustris* in post-fire area enhances the seedling growth increasing the soil moisture and chemical properties of the soil (Seo et al., 2013). In another study by Kim et al (2013a) on the response of *Pinus densiflora* seedlings on suitable fertilizer ratio showed significant cholorphyll a:b ratio in current year needles in fertilized plots compared to control plots. These results indicate that soil amendment due to addition of fertilizer lead to growth of both shoot and root parts of the plants which are necessary for securing competitiveness in an early seedling establishment phase. Kim et al (2013b) studied the comparison of growth variation between *Quercus mongolica* naturally regenerated coppiced sprouts and artificially planted seedlings in the eastern coastal forests burnt during 2000 with height (4.3 m versus 1.8 m) and diameter (4.4 cm versus 1.8 cm), respectively indicating that natural regeneration by coppicing may be a suitable approach for regenerating fire-burnt oak forests. Oaks (*Quercus sp.*) are also more adapted to dry sites like rocky outcrops, ridges and slopes compared to its associate (e.g., *Pinus densiflora*) (Shin et al., 2013) (Table 7).

Table 7. Growth attributes of red pine and oak sp. in rock, ridge and slope. Values in parenthesis are standard error (Shin et al., 2013)

Attribute	Rock		Ridge		Slope	
	Pinus densiflora	*Quercus sp.*	*Pinus densiflora*	*Quercus sp.*	*Pinus densiflora*	*Quercus sp.*
Height (cm)	52(5)	102 (6)	131 (19)	243(14)	277 (49)	466 (17)
Root collar diameter (mm)	17(2)	27 (2)	30 (5)	51 (3)	79 (6)	66 (3)
Shortest width of crown (cm)	41(3)	96 (6)	62 (4)	130 (2)	-	-
Longest with of crown (cm)	55(4)	131 (6)	77 (8)	162 (5)	-	-

Damages to forests from fires are intensive and extensive particularly in pine forests owing to the thin bark and high crown fuel load characteristics e.g., *Pinus koraiensis* (Kim et al., 2013c). As a result, the defense mechanism of the trees is weakened and Curculionid beetles proliferates (Ahn, 2013). Ahn (2013) also examined the effect of forest fire on physical properties of soil and reduction in soil erosion by making contour-aligned log erosion barriers using coarse woody debris. They found that destruction of soil structure by fires lead to increase in the bulk density with apparent reduction in the porosity of the surface soils thereby making the soil vulnerable to post-fire rain water runoff and soil loss and soil sediment yield reduction by the contour-aligned log barrier was 7 times higher (133.6 g/m^2) than in control (17.8 g/m^2). Consequently, this soil erosion control method has been the most effective method eventually developing into a natural barrier. Research on post-fire change in ant communities has revealed that forest fires influence the abundance of ant communities indicating that fires are damaging to ant population (Lee and Kwon, 2013).

Yeom et al (2013) studied forest fire education awareness, prevention and evacuation responses for residents in the Samcheok and their findings revealed that 74% of the residents were aware of forest fire prevention, 42% rated fire as dangerous. However, only 29% residents were aware of forest fire laws and, 22% knew about forest fire management and evacuation safety measures. The findings clearly underscore the importance to educate public on forest fire management and safety measures in the event of fire outbreak.

4.2.1 Forest restoration research strategies after fire

From the above research findings, following conclusion and strategies for fire can be made.

- Fertilization of planted seedlings in post-fire burnt areas increases the root and height growth required to secure competitiveness in an early seedling establishment phase.
- Establish standards for selecting fire-resistant species in fire prone areas from the list of fire-resistant species (Table 8).
- Post fire natural restoration may be practiced where regeneration (e.g. from seeds and sprouts) of the remaining trees that have sustained less damage is possible, until secondary forests are established. However, severely burnt areas may require rapid artificial regeneration depending on the climate, soil and erosion condition and economic (e.g., local mushroom harvest) objectives.

In fire-prone areas like Goseong, Samchoek, and Uljin, fire-resistant broadleaves should be promoted. Many fire-hardy species are characteristics of xeric environment and well adapted to drought or low soil moisture. The deciduous forests found in the ridges, slopes and valleys in the southeastern Unites States have developed thick bark and sprouting to withstand or recover from fire (Wade et al., 2000) resulting from historic fires. Fire response in northern hardwood often involves sprouting or root suckering, which does not change the canopy species composition (Beatty and Owen, 2005). The structure of the stand is altered, however, especially multiple stems per individual; but fires are not considered to have any long-term ecological significance in terms of forest regeneration (Fahey and Reiners, 1981). Thus, fire similar to intense anthropogenic disturbance, introduces a pathway of forest recovery that differs from natural (cyclones or storms) disturbances. Laarmann (2013) studied early evaluation of the effectiveness of different restoration treatments to rehabilitate managed stands in order to increase their naturalness. Restoration treatments were imposed on 30 - 60 years old conifer plantation including gap creation with and without adding deadwood, added deadwood without gaps, gaps plus over-burning, and control. Diversity of different groups responded differently to treatments with understory vegetation diversity increasing mostly in gaps with burning. Increased beetle abundance and higher species diversity were direct results of changed light conditions inside the canopy. Gaps with over burning had the greatest recruitment of tree seedlings. Stands that were homogeneous pre-treatment increased in heterogeneity in structural conditions and microclimatic conditions after treatments and abundance of different species groups increased.

- Improve species diversity and stand structure of single-species forests to multi-species and multi-storied forests for increasing resistance to fires and reducing damages from diseases and pests.

In order to enhance self-sustaining old forest characteristics in plantation stands, it is important to restore processes as well as structure (O' Hara and

Waring, 2005) which can be achieved through various silvicultural treatments as given below.

During plantation establishment, species can be randomly mixed at the planting stage, or planted in alternate rows to provide better access for later harvesting of selected species. Seedlings can also be planted in species groups to minimize interspecific competition.

Variable density thinning is one approach that deliberately leaves trees on variable spacing so that some residuals are nearly in open-grown conditions whereas others are in heavy competition (Figure 23) resulting in variety of tree-sizes in an even-aged stands (Thornburgh et al., 2000).

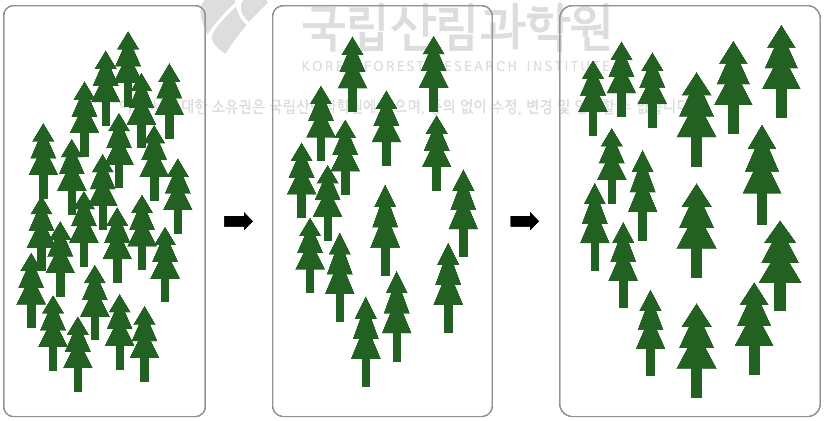

Figure 23. Variable density thinning (residual trees are thinned to have different amounts of growing space (middle) and grow to form more variable structures (right) (O' Hara and Waring, 2005)

Stands generally acquire more structural diversity as they age (Oliver and Larson, 1996) so that a simple means to enhancing diversity in even-aged stands is to extend rotations beyond the economic and volume-based limits commonly used for timber production objectives.

- Develop diverse stand structures like cores, corridors and forest edges between plantation (Bowers, 2013).
- Promoting natural regeneration (e.g., seeds and sprouts) may be desirable in a low fire damages coppicing oak forests while artificial planting should be followed for regenerating severely burnt forests taking into account the climatic, edaphic and management objectives.
- Contour log terracing in the post-fire burnt areas is the most effective technique for reducing soil erosion and adding nutrient budgets promoting tree regeneration.

- Compare natural regeneration versus artificial planting methods in terms of survival, performance and cost-effectiveness to inform forest restoration decisions.
- Education on forest fire prevention, management and evacuation safety measures in the event of catastrophic forest fire outbreak for the fire vulnerable communities need to be continued.

Table 8. Fire-resistant tree species by climate zone (KFRI, 2010b)

Climate zone	Life-form	Fire resistant species
Cold temperate	Trees	*Ginkgo biloba, Quercus variabilis, Q. acutissima, Q. dentata, Zelkova serrata, Fraxinus rhynchopylla, Populus maximowiczii, Phellodendron amurense, Liriodendron tulipifera, Robinia pseudoacacia, Larix kaempferi*
	Medium tree	*Picrasma quassioides, Fraxinus sieboldiana, Sorbus commixta*
	Shrub	*Clerodendron trichotomum, Broussonetia kazinoki, Euonymus japonica, Poncirus trifoliata*
Warm temperate	Trees	*Quercus myrsinaefolia, Cinnamomum camphora, Cinnamomum yabunikkei, Ilex rotunda, Machilus thunbergii, Neolitsea sericea, Actinodaphne lancifolia, Myrica rubra, Distylium racemosum*
	Medium tree	*Viburnum awabuki, Daphniphyllum macropodum, Camellia japonica, Illicium religiosum, Cleyera japonica, Ternstroemia japonica, Litsea japonica*
	Shrub	*Eurya emarginata, Aucuba japonica, Fatsia japonica, Ilex crenata, Phlox paniculata*

4.3 Forest restoration in post-mine areas

In Baeku-Daegan Mountain System, restoration experiment on the slope of abandoned mines was experimented 4 years ago. Four vegetation restoration techniques namely; control (abandoned mine), geo-membrane, woodchip mulching and rice straw mulching were applied as seed soil bed (Kim et al., 2010) (Figure 24). Hydro-seeding was done with 30 cm soil covering after laying geo-membranes. The results indicated that geo-membrane has 60% cover with 6 number of plant species survived. The plant species were: trees (*Albizia julibrissin, Lespedeza cyrtobotrya, Pinus densiflora*); native grass (*Lespedeza* *cuneata*); exotic grasses (Tall fescue, and perennial ryegrass). Woodchip and rice straw mulching had equal vegetation cover (5%) with two and one species survival, respectively. In woodchip mulching, trees were; *Albizia julibrissin* and *Pinus densiflora* and in rice straw mulching trees were *Albizia julibrissin*. The study concluded that coverage ratio was highest in geo-membrane followed by rice straw mulching and woodchip mulching at 30cm of soil cover indicating that the use of geo-membrane can be an effective technique for vegetation restoration in abandoned mines.

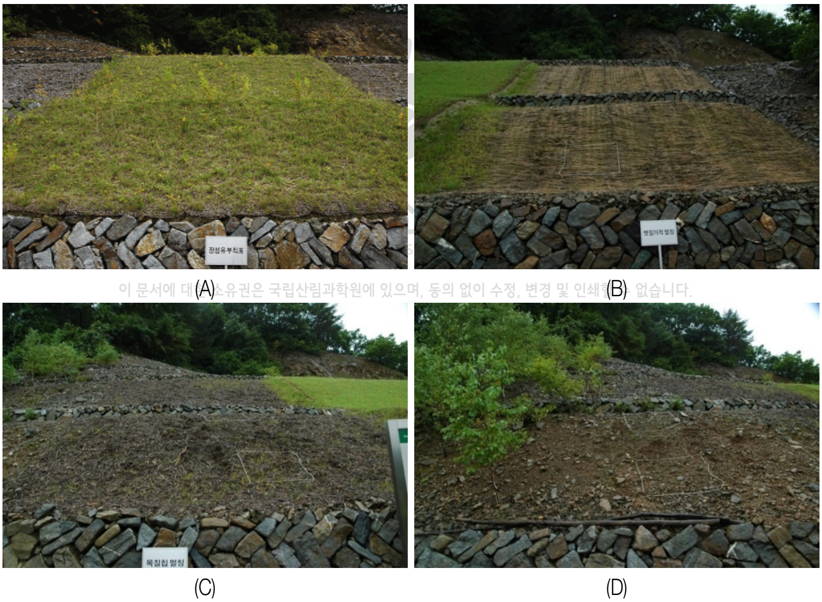

Figure 24. Abandoned mine plantation technique (A) geo-membrane, (B) rice straw mulching, (C) woodchip mulching, (D) control (KFRI archive)

Restoration of mine-waste mounds were experimented using direct hydro-seeding with soil molding in study plots with different soil depth and plant base materials (Figure 25).

(A)

(B)

(C)

Figure 25. Hydro seed spraying (A, B) and after completion (C) of mined site (KFRI archive)

At Pocheon, rehabilitation of abandoned quarry as a culture and art park was done in an area of 9.9 ha. Rehabilitation measures were; constructions of sculpture park, exhibition hall, concert hall, rest area, and outdoor cafeteria for the public (Figure 26).

(A)

(B)

Figure 26. Rehabilitation of abandoned quarry (A) before and (B) after (KFRI archive)

In an experiment to reforest post-mine area at Taebaek, *Pinus densiflora* seedling was planted and growth monitored. Data collected were; total height (cm), current year shoot height (cm) and root collar diameter (cm) by treatments. The analysis of the total height, current year shoot height and root collar diameter by treatments are given in the Table 9. One-way analysis of variance (ANOVA) showed significant difference ($F_{13, 183}$) = 20, $p < 0.01$) of height, current year shoot height ($F_{13, 183}$) = 5, $p < 0.01$) and root collar diameter ($F_{13, 183}$) = 8, $p < 0.01$) by treatments.

Table 9. Mean (± SD) red pine total and current year shoot height and root collar diameter by treatments

Treatment	Total height (cm)	Current shoot height (cm)	RCD (cm)
Soil and microbes	99 ± 22	32 ± 10	22 ± 6
Soil	92 ± 29	32 ± 11	22 ± 7
Control	84 ± 19	29 ± 09	18 ± 5
Microbes	86 ± 30	27 ± 10	19 ± 6
Lime + compound fertilizer (0.6%)	142 ± 23	42 ± 7	28 ± 6

Treatment	Total height (cm)	Current shoot height (cm)	RCD (cm)
Lime + compound fertilizer (0.6%) + microbes	186 ± 35	44 ± 11	33 ± 9
Lime (0.6%)	96 ± 30	26 ± 9	19 ± 6
Lime + microbes (0.6%)	113 ± 35	30 ± 9	23 ± 6
Lime (1.2%)	96 ± 22	29 ± 8	20 ± 5
Lime + microbes (12%)	77 ± 21	22 ± 7	16 ± 4
Peatmoss	83 ± 24	30 ± 10	19 ± 6
Peatmoss + microbes	78 ± 23	25 ± 9	16 ± 6
Terracotton + microbes	162 ± 52	39 ± 14	28 ± 10
Terracotton	166 ± 44	38 ± 10	28 ± 7

The treatment lime + compound fertilizer (0.6%) + micro-organism (LCFM) promotes superior sapling growth in terms of total height (186 ± 35cm, current year shoot height (44 ± 11cm) and root collar diameter (33 ± 9cm) compared to other treatments. Lime + compound fertilizer, terra-cotton + micro-organism and terra cotton treatment also resulted in good seedling height but not necessarily in the case of current year shoot and root collar diameter. The mean total height, current year shoot height and root collar diameter of the saplings are given in Figure 27, which illustrates superior growth in LCFM soil.

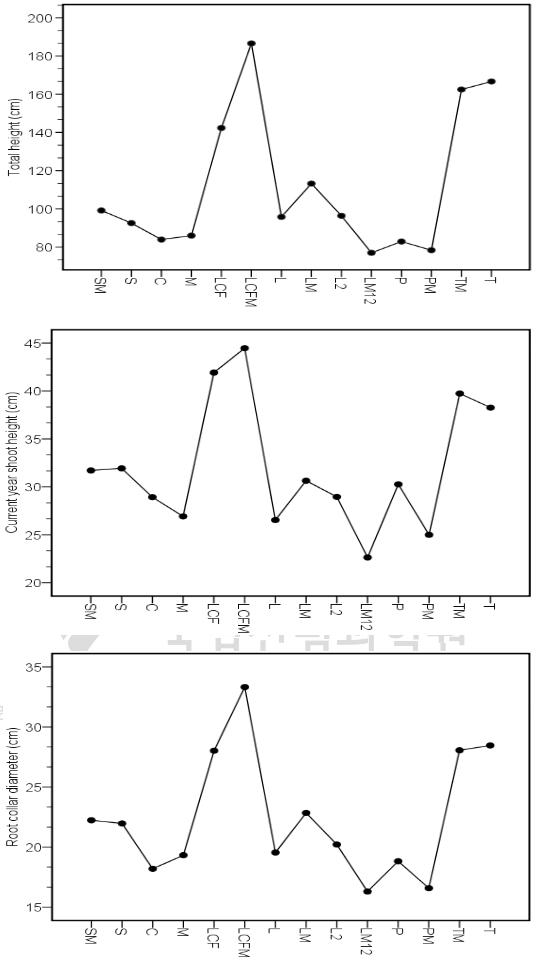

Figure 27. Mean total, current year shoot height and root collar diameter of Pinus densiflora seedlings in mine. Treatment: SM=soil + microbes; S= soil; C=control; M=microbes; LCF= lime + compound fertilizer (0.6%); LCFM= lime + compound fertilizer + microbes; L = lime (0.6%); LM= lime + microbes (0.6%); L2= lime (1.2%); LM12= lime +microbes (12%); P= Peat moss; PM= Peat moss + microbes; TM=Terra-cotton + microbes and T= Terra-cotton.

Kim et al (2013e) studied the purification ability of fast growing trees (*Populus euramericana*, *Populus tomentiglandulosa* and *Salix koreainsis*) in zinc abandoned mines in contaminated and non-contaminated sites. After 6 and 24 months, the study results showed that the shoot and root zinc content of the species in the contaminated area was 35.7 - 47.4 mg/kg and 44.2 - 157.6 mg/kg compared to 0.2 - 0.6 mg/kg and 0.3 - 0.5 mg/kg in non-contaminated site, respectively. The findings clearly indicate the effect of tree species particularly *Populus euramericana* as effective phytoremediation species. Jacobs (2013) pointed out that various morphological and physiological seedling quality attributes may be quantitatively linked to restoration success. For example, root system size is positively correlated with seedling survival because large roots allow greater exploitation of soil for nutrient and water uptake; carbohydrate content is correlated with root system size, thereby allowing seedlings to better avoid and tolerate stress common to mine reclamation sites; root:shoot biomass ratio reflects the water balance between root system uptake and plant demand and increasing root:shoot biomass ratio usually results in reduced drought stress.

4.3.1 Forest restoration research strategies after mines

From the above research findings, it can be concluded that:

- The use of geo-membrane with soil cover of 30 cm can be an effective vegetation restoration technique of abandoned mines.
- Lime + compound fertilizer + micro-organism promote superior sapling

growth of *Pinus densiflora* in terms of height and root collar diameter in post-mine restoration.

- In zinc abandoned contaminated areas, use of tree species like *Populus enramericana* can be an effective phytoremediation species.

4.4 Forest restoration in coastal areas

The Saemangeum Land Reclamation Project aims to reclaim 283 km^2 area of land by constructing the 33.9 km long sea dike connecting the Jeollabuk-Do Gunsan-si and Buan-gun County on the west coast of South Korea (Prime Minister's office 2011). The reclaimed land will be used for agriculture, industry, residence, recreation and landscape beautification cum windbreak forest development on the sea dike and address the shortage of land due to rapid urbanization fuelled by economic growth. The establishment of woody vegetation also contributes to protection of inland infrastructures from high salty and sand borne sea breeze by acting as wind break forests. For example, the coastline forest of *Pinus thunbergii*, *P. densiflora* and *Quercus variabilis* planted in 1930s in Japan has protected inland infrastructures against natural hazards (Shuto 1987). For the purpose of landscape beautification cum establishment of windbreak forest development, the Saemangeum reclaimed land of predominantly dredged sea soil is unsuitable for woody vegetation growth without any soil improvement. The dredged sea soil texture is silt clay loam, highly alkaline with pH ranging from 6.5 - 7.9, high salt concentration, poor

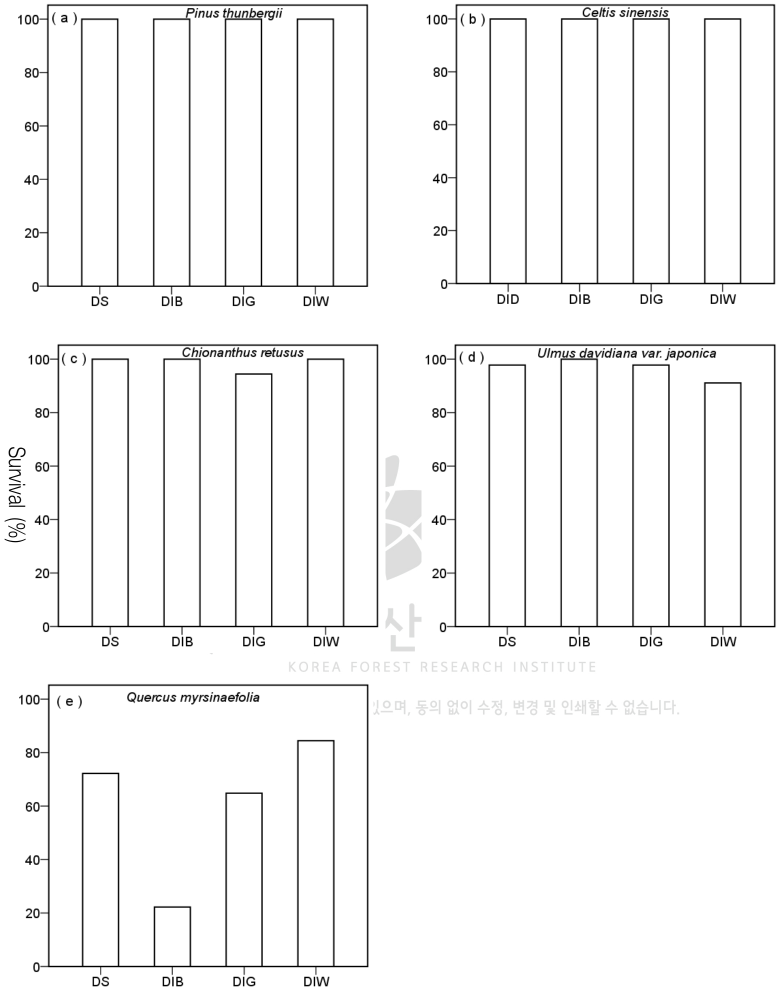

Figure 28. Survival rate of tree species by soil drainage substrata (a) Pinus thunbergii, (b) Celtis sinensis, (c) Chionanthus retusus, (d) Ulmus davidiana var. japonica, (e) Quercus myrsinaefolia. DS=dredged soil; DIB=dredged soil+improvement+bark; DIG=dredged soil+improvement+gravel; DIW=dredged soil+improvement+woodchip

soil permeability and drainage condition (Koo et al., 1998; Lee, 1996). Therefore, to establish woody vegetation with appropriate tree species under such soil condition, it is a challenge and requires an innovative eco-engineering solution. There are two methods to reclaim dredged sea soil after the sea dike has been built. Firstly, using of weathered parent material (rocks) as drainage substrata and secondly, improving the dredged sea soil by adding soil improvement materials are implemented. Soil salinity interception using gravel as a barrier has been demonstrated to be an effective substratum (Incheon International Airport Corporation 2000).

In the Saemangeum study area, soil drainage substrata applied were; gravel/rubble (crushed stones), broadleaves bark and wood chip to intercept salt accumulation through the process of soil capillary action. The specific objective was; to improve the dredged sea soil by using different soil drainage substrata namely; gravel, broadleaves tree bark and wood chip and to find out suitable woody tree species for landscape beautification cum windbreak forests development in the Saemanguem sea dike.

The study results show that there was variation in the survival percentage by species. Across the soil drainage substrata, *Pinus thunbergii* and *Celtis sinensis* showed 100% survival rate (Figure 28) followed by *Chionanthus retusus* with 100% survival except in gravel (94%); *Ulmus davidiana* var. *japonica* has 100% survival in bark but slightly lower in gravel (97%) and, woodchip (91%). Amongst species, *Quercus myrsinaefloia* has the lowest survival in woodchip (84%), dredged soil (72%) gravel (64%) and, bark (22%). The tree height and root collar diameter by soil drainage substrata, species and wind break are given in the Figure 29. There was no significant difference between the soil drainage substrata ($\chi^2_{(3)} = 0.684$, $p > 0.05$ Kruskal-Wallis test), however, significant difference in the height of tree species ($\chi^2_{(4)} = 110$, $p < 0.05$) was detected.

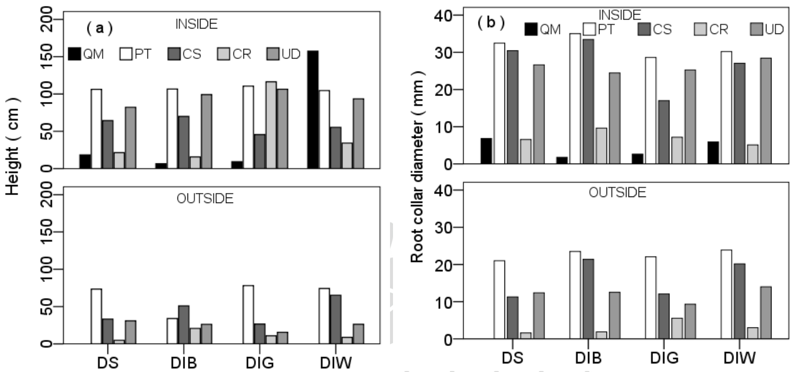

Figure 29. Tree species height (a) and root collar diameter (b) by soil drainage substrata and wind break. DS = dredged soil; DIB = dredged soil+improvement+bark; DIG = dredged soil+improvement+gravel; DIW = dredged soil+improvement+woodchip. QM = Quercus myrsinaefolia, PT = Pinus thunbergii, CR = Chionanthus retusus, CS = Celtis sinensis and, UD = Ulmus davidiana var. *japonica*.

The root collar diameter was not significantly affected by the soil drainage substrata ($\chi^2_{(3)} = 1.603$, $p > 0.05$), but significant difference in the root collar diameter among tree species was detected ($\chi^2_{(4)} = 139$, $p < 0.01$). Among the species, *Pinus thunbergii* and *Celtis sinensis* had the highest survival rate. However, in terms of height and root collar diameter, *P. thunbergii* performed better than other species in bark inside the windbreak.

Coastal forest restoration is a recent initiative in the ROK whose coastlines do not suffer from catastrophic natural hazards like tropical Asian countries except occasional monsoon-triggered cyclones and storms. With the start of the several disaster prevention forest projects by the KFS, attempts are being made and search for good practice continues. From the review of literature on coastline forest development primarily for prevention against natural hazards, following points may have to be considered in the future.

4.4.1 Coastal forest restoration research strategies

- *Pinus thunbergii* is a suitable tree species for coastal area reforestation.
- Forest width is one of the most important factors in mitigation of natural hazards. Over the width of the forest, energy is progressively dissipated by drag and other forces created by tree trunks, branches and foliage, as well as the undergrowth, as natural hazards passes through the forest (Forbes and Broadhead, 2007). Pine forest width of at least 20 meters is needed to withstand flow depths of one to three meters. For larger waves, width (w) would need to increase according to the relationship $W = 20(H/3)^{0.5}$, where H is wave height above ground, to maintain the mitigation effect (Shuto, 1987). Simulation results show that a 3-6 fold increase in energy from increased wavelength (period) resulted in only a small increase in energy transmission for width greater than 100 meters. However, for a narrower forest of 50 meters the loss in hydraulic force (drag force) reduction was more apparent. As such, increasing forest width will progressively reduce risk and potential impact.

- Forest density or spacing of trees (horizontal density) is another important consideration. The vertical configuration of above-ground roots, stem, branches and foliage (vertical density) defines the overall density (vegetation thickness) or the permeability of a barrier. Though forest density may have a less pronounced mitigation effect relative to width, density directly relates to the forest's ability to reflect natural hazards as well as absorb its energy. Moderate densities are the most effective in hazard mitigation. Vertical density, not just horizontal density, is an important factor in determining a forest potential for mitigation. A forest with sparse undergrowth and trees with few branches at lower levels will provide less mitigation than a forest with high vegetation density from the ground to the canopy.

- Increases in age, diameter and height generally enhance the mitigation effects of coastal forests. Diameter growth also enhances the breaking strength of trunks and branches. It also raises the resistance of the forest being toppled, up to a point after which resistance falls. When stems mature, the rate of increase in strength, stiffness and diameter slows relative to accumulation of mass in the canopy such that mechanical failure is more likely if the tree is subjected to an external force (Niklas and Spatz, 1999)

- Height of the dominant and co-dominant trees in a coastal forest has a direct bearing on the forest frontal area projected towards hazards. The taller forest is the greater reflective area of the barrier wall.

- The make-up of the coastal forest has important implications for the level of natural hazard mitigation. Two critical aspects of tree species composition and forest type are the vertical configuration of roots, bole, branches and foliage, and understory development. Variation in vertical density affects drag resistance at different heights in the forest, and hence overall resistance. Tree species that retain lower branches or have stilt rooting contribute significantly to density at lower layers.

- Density, diameter, height, age and the other parameters that effect mitigation are not independent of one another. They, therefore, have to be considered in an ecological, social and economic context to assess what is and what is not possible in terms of hazard mitigation. For example, it may not be possible to establish large diameter trees on shallow sandy soils. Each forest types and species have specific ecological requirements for successful establishment.

4.5 Forest restoration in pests and diseases affected areas

According to Han et al (2013) in recent decades, two major factors are related to the increase of pests and diseases threat to forests, global trade and climate change (Dukes and Mooney, 1999; Liebhold and Tobin, 2008). The volume, speed and variety of global trade have increased the incidences of forest pests to move across international borders and require cross border action to prevent the movement of pests and their establishment in the new areas. Climate change has aggravated the likelihood of pest movement, establishment and severity of impacts of both native and introduced pests. Due to global warming, potential host trees may become more susceptible to pest development because of climate-induced stress caused by increased drought and extended growing seasons (FAO, 2010). Among forest pests, the invasive species have potentially devastating effects on biodiversity of natural communities and economy (Mack et al., 2000). Of the major forest pests in the ROK, most are exotic species such as pine needle gall midge, pine wood nematode, black pine blast scale and fall web worm. Past and present forest restoration intervention that has been carried out in the pests and diseases affected areas is briefly described below.

Figure 30. Control method of pine wilt disease (A) fumigation, (B) burning, (C) aerial spraying (D) trunk injection (KFS archive)

4.5.1 Pine wilt disease

Restoration of pine wilt disease include; felling and fumigation, trunk injection of nematicides, aerial spraying of insecticides, and preventive clear-cutting of neighbouring asymptomatic trees (Shin et al., 2008; Kwon et al., 2011). The felling and fumigation of the infested trees has been the most effective control method (Figure 30). Infested trees are cut into 1m long logs and placed in 1 - 2 m^3 wood piles. Metham sodium at 1 litre/m^3 is sprayed onto the tree beetles on pine twigs (Shin et al., 2008). Negative effects of aerial spraying on the forest ecosystems are less severe than expected based on the impact on anthropod communities (Kwon et al., 2011). Recently, silvicultural control through preventive clear-cutting method and manual removal of logs for the suppression of pine wilt disease is practiced (Kwon et al., 2011).

4.5.2 Pine needle gall midge

To control pine needle gall midge, several methods such as trunk injection, soil application of systematic pesticides, introduction of parasitoids and silviculture method are followed. Trunk injection involves application of systemic pesticides such as phospharnidon, imidacloprid, acetamiprid to pine trees in June when pine needle gall midge oviposits its egg on the base of pine needles. The spraying of systemic pesticides such as imidacloprid or carbofuran on the soil around the trunks of the pine trees is restricted to nursery and ornamental trees due to its negative effect on the soil ecosystem

(Shin et al., 2008). The silviculture method improves the health of pine forests and reduces tree mortality caused by pine needle gall midge through thinning forest trees with the removal of trees that are growing too close. The controlled area was drastically reduced from 2001 - 2004 but again increased from 2006-2009 (Figure 31).

4.5.3 Black pine blast scale

Generally, the trunk injection of imidacloprid or phosphamidon was used to prevent expansion of black pine blast scale. In addition, buprofezin was applied through aerial spraying. However, its control was not effective (Shin et al., 2008). There are 53 known species of natural enemies including spiders and beetles such as *Chilocorus rubidus*, *Harmonia axyridis*, and *Brachyponera chinensis* (Kim and Lee, 1998), but reduction is estimated to be only 11% (Shin et al., 2008).

4.5.4 Fall webworm

The fall webworm population has declined since 1979 probably due to suppression by natural enemies. Application of pesticides such as fenitrothion, lambda cyhalothrin, diflubenzuron and chlorfluazuron is used to control. Interestingly, its population is observed in urban forests only in the ROK (Shin et al., 2008). Natural enemies play a key role in the suppression of fall webworm with mortality exceeding 95% (Kiritani and Morimoto, 2004). Natural enemies contribute to population stabilization of fall webworm and control costs have gradually decreased since 1990s indicating a decrease in damaged area.

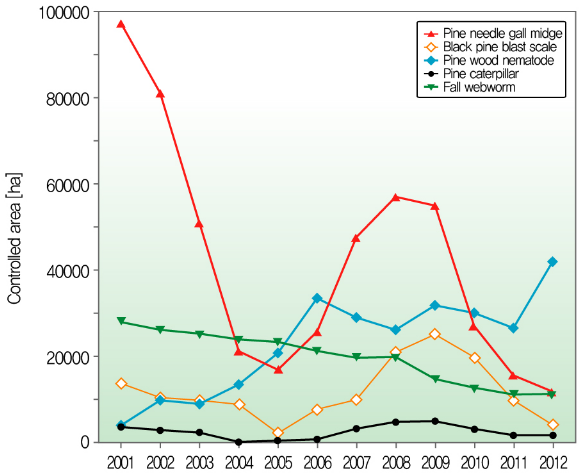

Figure 31. Controlled area of forest by pests and diseases

4.5.5 Forest restoration research strategies of pests and diseases affected areas

The expansion pattern of pine needle gall midge, black pine blast scale, pine wood nematode show “type 2” pattern whereas fall web worm follow “type 1” pattern according to the stratified modeling of Shigesada and Kawasaki (1997) suggesting that human mediated movement of exotic species contributes to species spread by accelerating expansion. Moreover, the expansion speeds were positively correlated with the dispersal capacity (Choi and Park, 2012). Forests nearby roads, railways, and residences are highly threatened by exotic species. In addition, climate change could trigger the movement of pests and diseases from south to north with increase in temperatures.

- Control activities of pine needle gall midge, black pine blast scale, and fall web worm should continue to focus on density reduction and intensive control for curtailing expansion in the early stages of dispersal (e.g., pine wilt disease) and legally restricting the transportation of pine trees from the pine wilt disease areas.
- A mix of artificial and silvicultural methods of control should be applied depending on the pests and diseases biology and expansion pattern
- The use of natural enemies on the suppression of invasive species should be species-specific.
- Effective management strategies for control of invasive species need to be continuously evolved in accordance with their biological traits and invasion phase.

4.6 Forest restoration strategies for climate change

Since 1990s, climate change has become a hot issue and the role of forested ecosystem to sequester CO_2 and other green house gases (GHGs) as sinks have been well recognized and given high priority. Forest play an important role in the global carbon cycle because they store large quantities of carbon in vegetation and soil, exchange carbon with the atmosphere through photosynthesis and respiration and become atmospheric carbon sinks (i.e., net transfer of CO_2 from the atmosphere to the land) during re-growth after disturbance (Brown et al., 1996). But human and natural disturbances (e.g., climate change) have the potential to alter the magnitude of forest carbon stocks and the direction of forest carbon fluxes through changes in land use and management and thus alter the role of forests in global carbon cycle (Ciccarese et al., 2005). Loss of forests and degradation caused significant CO_2 flux to the atmosphere (Dixon et al., 1994). During the 1990s, tropical deforestation and forest degradation resulted in an estimated average annual CO_2 emission of about 25% of the total global anthropogenic carbon emission (Ciccarese et al., 2005).

Land use change and forestry activities can mitigate carbon emissions by conserving or expanding existing carbon storage in forest ecosystems and by substituting sustainably grown wood for energy-intensive and cement-based products. Examples include increasing the area or carbon density of forests by afforestration, rehabilitating degraded forests and altering the management of natural forests and plantation to sequester more carbon longer by lengthening rotation and reducing logging impacts (Mayers and Goreau, 1991; Brown at al., 1996; Kauppi and Sedjo, 2001). Most of these practices have social, economic and ecological benefits in addition to their possible role in mitigating climate change (Brown at al., 1996) and payment for the carbon conserved and sequestered may provide incentives for forest restoration.

According to Ciccarese et al (2005) in a regulated forest, forest-level planning and management can ensure that there is no net release of carbon, although fluxes of carbon between the forest and the atmosphere will certainly occur. Carbon stocks of the entire forest remain constant or even increase, and a few forest units are harvested each year. Just as annual volume harvests are scheduled to remove less than annual volume growth, managers can plan regular harvesting and tending activity to maintain carbon stocks. A manager may wish to reduce the risks of non-compliance by planning to harvest less than growth.

Afforestation and reforestation projects can effectively address saturation constraints by producing bio-fuels and wood products that replace fossil fuels and energy-intensive non-timber building materials such as steel or concrete, thereby expanding the scope for emission reductions and allowing repeated CO_2 emission savings. Major carbon pools in forestry projects are above and below ground biomass, litter, deadwood, soil organic carbon and mineral soils.

Forest soils represent a short to medium carbon storage, and contain more carbon than all terrestrial vegetation and atmosphere combined. The magnitude and quality of soil carbon storage depend on the complex interaction among climate, soils, and tree species and their management, and chemical composition of the litter as determined by the dominant tree species (Kim et al., 2013d). Kim et al (2013d) assessed the potential role of forest soil in carbon sequestration according to the 5^{th} National Forest Inventory data for 4 years from 2006 - 2009 by forest types in the ROK. They found the mean carbon storage in organic layers of 5.6 tons/ha in conifer forest, 4.9 tons/ha in mixed forests, 4.3 tons/ha in deciduous broadleaves and by forest type; 50 tons/ha in conifer forest, 55.5 tons/ha in mixed forest and 78.5 tons/ha in deciduous broadleaves (Kim et al., 2013d). In the mineral soil, organic carbon tends to decrease with increasing soil depth. A strong positive linear relationship (R^2 = 0.8) between the litter fall dry mass and organic layer carbon was detected in each forest type with a highest in conifer forest underscoring the importance of conifer forests litter fall and decomposition rate in the conservation and management of carbon in forest soil (Table 10).

Table 10. Soil organic carbon content in organic layer (Kim et al., 2013d). Values in parenthesis are standard deviation

Horizon	Forest type	Dry weight (kg/m^2)	Organic carbon (%)
Litter	Conifer	0.69 (± 0.58)	45.7 (± 5.2)
	Mixed	0.60 (± 0.66)	43.5 (± 5.8)
	Deciduous	0.48 (± 0.33)	42.0 (± 4.3)
Fermentation	Conifer	0.87 (± 0.73)	38.5 (± 7.6)
	Mixed	0.88 (± 0.74)	33.7 (± 7.8)
	Deciduous	0.62 (± 0.70)	34.6 (± 5.6)
Humus	Conifer	1.56 (± 1.31)	42.1 (± 6.4)
	Mixed	1.48 (± 1.39)	38.6 (± 6.8)
	Deciduous	1.10 (± 1.03)	38.3 (± 5.0)

Depending on the management, soils can be either a source or sink of greenhouse gases e.g., carbon dioxide, methane, nitrous oxide, etc. In forest soils, the production and sequestration of these 3 gases are biologically mediated but also strongly controlled by man-made disturbances (Kim, 2013).

For example, reduced methane consumption and CO_2 enrichment were observed with increased levels of soil moisture as a result of increased leaf stomata closure and loss of water through evaporation from the forest floor. In the event of climate changes:

- Priority should be given to the conservation of the high mountain vegetation and species of the habitat ranges in anticipation of significant global warming. Research on bioclimatic ranges and adaptation abilities of plant and animal species would be required to adapt to climatic change.

5. Factors of successful forest landscape restoration

5.1 Forest policy synergy with related policies

The success of forest landscape restoration in the ROK owes to far-sighted Government policies, strategies and plans at large. The ROK established an intensive provisional Government system with a powerful tenacity to restore forests through centralized system (Park, 1998a). As an integral part of the National Forest Plans, the Government introduced forest planning and management projects for establishing forest conservation and development system based on the land use classification and detail scientific reforestation plans. Also, strict regulation was introduced to protect reforestation and regulate access to reforested mountains areas. The Government restored vegetation in 142,512 ha of shifting cultivation land devoid of forest vegetation during a span of 15 years from 1968 - 1980 (Park, 1998a). Since forest devastation occurred in rural villages mostly due to excessive fuelwood harvest, fuel woodlots were established particularly in mountain villages to prevent further forest destruction (Bae et al., 2012). The Government also limited domestic timber harvest to 15% of the annual growth of the forests (Park, 1998a).

Secondly, the success has not occurred by chance. The Government policies outside the forest sector significantly contributed in the restoration of forest and forest resources. Outside forestry sector policy coordination and implementation of forestry projects between the forestry and allied industrial sectors approach was undertaken to prevent and halt deforestation and forest degradation activities. For example, introduction of anthracite as wood fuel substitute saved forests from fuel wood exploitation in collaboration with the Ministry of Commerce and Industry (Bae et al., 2012). The production and use of coal briquettes substantially increased in urban areas from 1960s resulting 7% of urban homes using firewood for cooking and heating while rural homes began to use coal briquettes from 1970s onwards only (Bae et al., 2012). In addition, the substitution of firewood with fossil fuels complemented by rural to urban migration of population led to decreased firewood consumption resulting in continuous increase of forest cover and stocking from 1960s (Bae et al., 2012). The national police force was mobilized to implement Government policies and prevent illegal logging, slash and burn agriculture, and regulate visit in reforestation mountain villages (Bae et al., 2012). The Government policy of importing large-size timber logs from outside countries and export in the form of high value finished products greatly reduced the domestic forest dependence on timber products. The excess off-cuts and wood wastes were used for domestic consumption as well.

5.2 Public participation

The KFS contributed to the success of the national reforestation plans by not only reforestation of denuded forest land but also creating employment opportunities involved in the reforestation success (KFS, 2012b). The creation of nation-wide “tree planting period” and “tree tending period” with active participation of local communities, national organizations, schools and civil societies lead to public awareness on environmental issues and valuing forests (Figure 32). Forest fraternities (mutual aid association) were created and leaders were trained to reinforce reforestation activities (Park, 1998a). Civil societies also actively participated in tree planting and tending operations. Local residents planted and tended trees in the mountain villages. Government encouraged and trained local people to establish and manage village nurseries, participate in the planting of trees and implementation of erosion control measures (KFS, 2012b).

Figure 32. Public participation in tree planting (KFS archive)

5.3 Integrated planning and coordination

The cooperation among Government agencies, Non-Governmental organizations (NGOs), civil societies and local communities was infused with the spirit of "Saemaeul Undong" meaning "New Village Campaign" (Lee, 1984). It is said that the movement strongly fostered the community mobilization and participation in bringing about rural development (Lee, 1984). Forests and forestry was recognized as an integral part of rural development landscapes. The First forest plan was directly connected to the Economic Development Plan and National Comprehensive Development Plan (Bae et al., 2012). Recognizing the role of forestry in rural development, the KFS was shifted from the Ministry of Agriculture and Forestry to the Ministry of Internal Affairs in 1973 (Lee and Suh, 2005; Bae et al., 2012) to carry out reforestation effectively (Kim, 1999). The institutional strengthening of the KFS and capacity building of professional foresters was actively pursued.

5.4 Good governance and leadership

To steer changes, good governance sought public participation, mobilizing resources and creating a sense of responsibility and accountability in the reforestation program. In the mid-1970s, the Government of President Park Chung Hee (President Park) advocated the policy of self-sufficiency in domestic food production and consumption and bridged inequity between central, provincial and village agricultural communities in order to promote sustainable economic growth (Park, 1998a; Bae et al., 2012). Thus, he promoted the "Saemaeul Undong" (New village) movement throughout the nation. The movement aimed at creating a sense of diligence, self-reliance and cooperation among the public. The "Saemaeul Undong" movement united the reforestation plan (Figure 33) to cooperate and implement to protect and conserve the forests and concomitantly introduced village projects as economic incentives for protection and conservation of reforestation, erosion control and, graveyards preservation. President Park led an efficient and effective administration and played a strong and visionary role. Bae et al (2013) writes "President Park was the epicenter that oversees and promotes coordination of various projects, plans and collaboration among different agencies. The recognition and role of an authoritative power are important for a developing country when dealing with common-pool resources such as forests." The early completion of first forest plan is a direct result of the strong Government-led efforts under the influence of President Park (Bae, 2007). Local forestry associations and county forestry cooperatives provided the direct and indirect extension services to support the Government's reforestation policy by offering technical training to rural communities. The KFS and its research organizations supported the reforestation policy by developing and transferring forestry technology such as developing tree species suited for reforestation and erosion control technology (Bae et al., 2012). The KFS and above all, the astounding reforestation success is the result of close cooperation and collaboration between the Government at central, provincial and municipal level and public, who reciprocated with loyalty and trust to overcome the ecological and economic devastation left behind by colonial regime and Korean War.

Figure 33. Tree planting by the President and his family (KFRI archive)

6. Future Direction

6.1 Forest restoration at landscape level

Restoration is defined as the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed (SER, 2012). In forestry terminology, the forest restoration means "actions to re-instate ecological processes, which accelerate recovery of forest structure, ecological functioning and biodiversity levels for deriving ecological, economic and social benefits for human well-being" (Maginnis and Jackson, 2007). Forest restoration is a specialized form of reforestation, but it differs from conventional tree plantation or greening in that its primary goals arebiodiversity recovery and environmental protection. Forest landscape restoration is an approach to forest restoration that seeks to balance human needs (sustainable livelihood, poverty reduction and preservation of human-forest culture) with those of biodiversity, thus aiming to restore a range of forest functions and accepting and negotiating the trade-offs between them (Mansourian et al., 2005). Deriving from these broader goals, the goals of forest landscape restoration in the ROK aim to restore provisioning services (forest food, medicines and wood based raw materials for construction) and environmental functions (preserving watersheds thereby regulating water quality and quantity for drinking, irrigation, industrial use); improving and expanding habitats for endangered species; soil stabilization and reducing the risk of landslides and soil erosion and; recreational value to human health (Lim and Kwon, 2013).

6.2 Principles of forest landscape restoration

According to the International Union for Conservation of Nature (IUCN), definition of forest landscape restoration is "a planned process that aims to regain ecological integrity and enhance human wellbeing in deforested or degraded forest landscapes and beyond" (Maginnis and Jackson, 2007; Mansourian et al., 2005). Ecological integrity is defined as "maintaining the diversity and quality of ecosystems, and enhancing their capacity to adapt to change and provide the needs of future generations" and human well-being as "ensuring that all people have a role in shaping decisions that affect their ability to meet their needs, safeguard their livelihoods and realize their potential."

Thus, the success of FLR should address socio-economic needs (sustainable wood and non-wood production, ecotourism and quality of health and life, sustainable livelihood security) and ecological needs (habitat, ecosystem and ecological connectivity and soil erosion protection). This inevitably involves trade-offs between different site level functions and key stakeholders should be involved in determining how to balance the trade-offs required for sustainable solutions. The overall landscape benefits are therefore more important than choices relating to an individual stand or site-based forest landscape restoration. FLR should increase both forest quality and quantity at a landscape scale from the perspectives of both ecological integrity and well-being.

The potential contribution that forest restoration action can make to both biodiversity conservation and improvement of human livelihood is increasingly being recognized by policy makers (Nellemann and Corcoran, 2010); The Secretariat of the Convention on Biological Diversity 2010 and subsequently incorporated in a number of international policy initiatives, such as the Convention on Biological Diversity (CBD). The Bonn Challenge 2011 aims to restore 150 million ha of lost forests and degraded lands by 2020 (Saint-Laurent, 2011). The IUCN estimates that the annual benefits to national and local economies of restoring 150 million hectares world-wide are approximately US$ 85 billion/year, which could also sequester an additional 1 $GtCO_2$ per year reducing the current emissions gap by 11 - 17% (Saint-Laurent, 2011).

Some underlying principles of forest landscape restoration have to be met as identified by reference to the Segovia minutes, the draft World Wide Fund for Nature (WWF) and IUCN position on plantations, the target set at Bali Action Plan. Further, Newton and Tejedor (2010) summarized the important findings from the case studies of dry land in America and highlighted the difficulty of developing a generally applicable procedure for implementing FLR. They pointed out that what is required is rather an approach that is sufficiently flexible so that it can be adapted to any local situation. The main lessons learned from their research findings are that FLR will need to be adapted to the particular circumstances of any given context, in order for it to be effective. They proposed a revised set of principles as given below.

6.2.1 Ecological integrity of forests

FLR aims to restore ecological integrity and does not simply replace one or two attributes of forest functions. Under the forest landscape restoration, some forests may reasonably be plantations or unnatural tree cover, e.g., wood fuel, timber and non-timber plantation to fulfill legitimate social and economic purpose. However, to qualify as forest landscape restoration, there should be a net increase in naturalness of forests within the landscape. The implication is that forest landscape restoration will balance natural regeneration over conventional tree planting or artificial regeneration. There should also be a harvesting and regeneration system that involves minimum human interference with the natural ecological cycle. An important underlying theme of the approach is that more the natural forest mosaic should have improved resilience to environmental change resulting from climate change, forest fires, storms and cyclones.

6.2.2 Environmental benefits

Forest management practice (i.e., harvesting and regeneration methods or plantation methods that result in either on-site or off-site environmental damage such as soil erosion, fertilizer run-off, pesticides spray drift or downstream hydrological effects, and etc.) is incompatible with the wider aims of forest landscape restoration. Therefore, the principles for environmental benefits are more stringent than for either authenticity or social benefits at the site and landscape level.

6.2.3 Livelihood security

FLR aims to enhance the provision of ecosystem services to humans at the landscape scale, and thereby contributes to improved human well-being. However, FLR may not improve social well-being at every site. However, the definition of FLR is clear that people's livelihood should improve at the landscape level. FLR seeks to enhance human well-being based on the principle that the joint objectives of enhanced ecological integrity and human well-being which cannot be traded-off against each other at a landscape scale. FLR implementation is at a landscape scale; in other words, site-level decisions need to be made within a landscape context. Equally important is the involvement of key stakeholders in the policy and decision-making process, which help them to ensure the issues relating to human well-being are fully addressed. As FLR provides a vehicle to halt and reverses forest loss and degradation, a key element in the approach is to address causes that drive forest loss. However, many of them are linked to human livelihood and include issues outside the traditional conservation boundaries like gender, equity and land tenure. Actions that aim to reverse the underlying causes of forest degradation at a landscape level are of necessity and require matching long-term commitment from the various partners.

6.2.4 Adaptive Management

Adaptive management can be defined as the integration of design, management and monitoring to systematically test assumptions in order to adapt and learn (Newton, 2010). Therefore, FLR approach should be considerably flexible and customized to local circumstances taking into account the considerable differences in forest loss and degradation; patterns of species richness and composition; use of forest resources; effectiveness of different restoration approaches; pattern and rate of forest recovery; policy context and recommendations; and the local value of different ecosystem services. The approach involves systematically trying different management actions to achieve desired outcomes based on monitoring results. Adaptation involves changing assumptions and interventions in response to the information obtained as a result of monitoring. A monitoring program is, therefore, essential if an adaptive management approach is to be effective. The adaptive management approach is important to measure the effectiveness of FLR approach to be responsive to social, economic and environmental change. It, therefore, requires both an adequate monitoring program and an appropriate learning process (Figure 34).

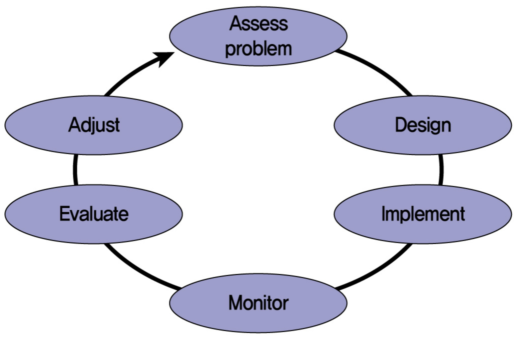

Figure 34. Adaptive management cycle (Bowers, 2013)

6.2.5 Participatory process

FLR should be a participatory process, requiring the engagement of key stakeholders in planning, implementing and monitoring the progress to be successful. The stakeholders' views and concerns must be taken on board throughout the process in order to develop ownership, responsibility and accountability to national and local forest landscape restoration strategies and plans.

KOREA FOREST RESEARCH INSTITUTE

7. Forest landscape restoration at landscape level

According to the Global Partnership on Forest Landscape Restoration (GPFLR), FLR only works on a scale that can accommodate a balanced package of forest functions (Saint-Laurent, 2011). Only when large areas of landscape are treated as a whole, can the different interests be accommodated and reconciled. The issues such as biodiversity conservation and watershed management could be tackled in a coordinated way and the benefits are realized more at a landscape level than a particular site. Furthermore, many ecological services are public goods and cross land use, ownership and district boundaries and enhancement of benefits requires management at a broader landscape level with the participation of both public and private owners (Kline et al., 2000; Gottfried at al., 1996; Boyd and Wainger 2002; Johnson et al., 2002). However, the size and nature of the landscape can only be determined under local circumstances. From the functional point of view "a landscape is a geographical space in which the process or object of interest is completely expressed or functions. It includes not only the biophysical components of an area but also social, political, psychological and institutional attributes" (Farina, 2006).

8. General strategy to forest landscape restoration

FLR is a flexible process that will need to be adapted to national and sub-national or provincial level considering the ecological, socio-economic, cultural and political context. World Wide Fund for Nature (WWF) and IUCN have developed a number of landscape approaches to help address broad scale planning and decision making to arrive at strategies and plans, which could provide as general guidelines in determining where restoration could be used most effectively (Dudley et al., 2005; Dudley, 2007) (Figure 35). These general guidelines modified and adopted from WWF and IUCN (Dudley et al., 2005) could be customized to suit the local circumstances.

KOREA FOREST RESEARCH INSTITUTE

9. Measuring progress on forest landscape restoration

Monitoring and evaluation is essential in forest landscape restoration program to facilitate adaptive management. It has been identified as one of the most critical elements in measuring success particularly in a large-scale restoration effort, which span several decades involving many different actors. Mistakes need to be redressed and improvements need to be made. Proper monitoring tools that are adapted to a large scale need to be developed and then applied rigorously. In this context, Newton and Tejedor (2010; Newton, 2010) outlined a framework on measuring FLR progress that can lead to a number of potential benefits and underscored the interdependence between these relationships (Figure 36). They pointed out that FLR can potentially lead to a number of different impacts, including increased forest connectivity, increased provision of ecosystem services, mitigation of threats and etc. These may have additional impacts, for example on biodiversity and both economic and environmental risks. Together, such impacts may contribute to development policy outcomes, such as conservation of biodiversity, alleviation of poverty, development of sustainable livelihoods and preservation of forest cultural heritage in order to contribute to the national vision of “green nation.” However, in order to achieve these development outcomes, good forest governance is important.

Figure 35. Where and How to start Forest Landscape Restoration?

1. Defining own conservation problems, solutions and targets : An essential first step of any forest landscape restoration program is the identification of landscape, problems & solutions, and the targets for restoration. Targets should ideally contribute to wider ecological and socio-economical objectives at a landscape scale.
   Tools / techniques : Remote sensing and GIS techniques together with statistical modeling approaches to identify both the pattern and proximate causes of forest defragmentation and loss; causes and effects relationships; research studies; literature reviews; ecological and socio-economic surveys; focus groups; key informant interviews; and etc.
   Outputs : recognition and common understanding of the forest loss and degradation; root causes and effects; solutions and targets.

2. Learning about the needs and expectations of others : It is important to get an initial idea about the other key stakeholders and their relationships, what and which function(s) need to be restored?
   Tools / techniques : Stakeholder analysis and mapping; etc.
   Outputs : Stakeholders' involvement and participation, and partnership building for restoration programs and project(s).

3. Setting objectives and linking restoration to large-scale conservation vision : a vision, priority areas and activities for restoration should be developed within an integrated planning and management with "protect–manage–restore" approach; determine current or potential benefits from forest restoration (e.g., biodiversity, environmental services, recreation, subsistence and commercial). Answer the questions: restoring what, for whom and why?
   Tools / techniques : Conceptual modeling; log frame; threat matrices, etc.)
   Outputs : vision and strategy with priority areas (degraded and eroded forest watershed landscapes, burnt forests, cyclones and storms affected areas, pests and diseases affected areas and restoration of keystone species of plants and animals, etc.)

4. Implementation action plans : actions will take place at the site level (e.g., creating right conditions for natural regeneration, artificial tree planting to reconnect forest fragments and/or loss ensuring connectivity, community initiatives to improve fire management, etc.)

Tools / technique : Work planning matrix; responsibility chart; budgeting; etc.
Outputs : Medium and annual action plan(s)

5. Monitoring and learning : Landscape approach to forest restoration is new. Therefore, it is important to ensure that progress is monitored effectively. The lessons learned should be used to improve programs and projects as they develop. Good policies and practice are transmitted beyond the landscape level.

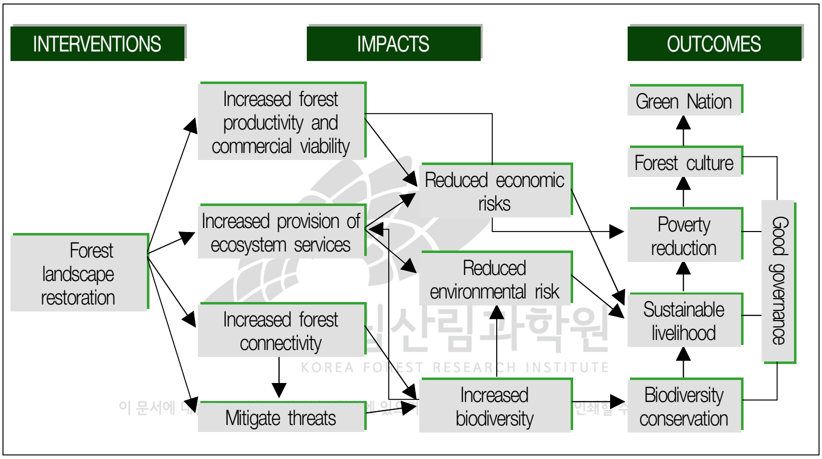

Figure 36. Schematic diagram of relationship between potential impacts of forest landscape approach and potential outcomes (Modified from Newton, 2010)

This conceptual model offers a generally applicable description of the FLR process, and could potentially provide a framework for monitoring its impacts and effectiveness contributing to overarching development outcomes of ecological integrity and human wellbeing. The framework can be used to develop the criteria and indicators for testing at the landscape level or national level and to review the relevance of national policies, and adjust forest landscape restoration, management decisions and practice. Positive success in FLR approach will be demonstrated by the positive trends corresponding to the criteria and indicators overtime (Castaneda, 2000).

The criteria for measuring FLR given below is based on the sustainable forest management criteria developed for the ROK as part of the Montreal Process on Criteria and Indicators for the Conservation and Sustainable Manag ement of Temperate and Boreal Forests (English.forest.go.kr). However, the sub-criteria and indicators are designed to measure and monitor forest landscap e restoration success (Table 11). The list is tentative, and further research is required to refine, test and validate the indicators depending on social, econo mical and ecological context. Some of these indicators would be difficult to measure in practice, and therefore, measurable proxies may need to be used.

Table 11. Tentative criteria and indicators for measuring FLR progress

Criteria/sub-criteria	Indicators
1. Conservation of biodiversity	
1.1 Forest composition, structure	Proportion of natural forests (i.e., forest made up of natural species and allowed to develop natural characteristics) Species richness and composition Forest proportion by different succession stages Distribution pattern of endangered, endemic plant species Demographic and genetic structure, genetic diversity
1.2 Forest ecosystem function	Distribution pattern of keystone, endemic animals Microclimate and nutrient cycling Mosaic or ecosystem heterogeneity
1.3 Forest Fragmentation	Area of forest compared to original forest extent Area of contiguous forests

Criteria/sub-criteria	Indicators
2. Productive capacity of forest ecosystems	Forest by production functions Wood and non-wood forest products (fuel, fiber, food, medicines)
3. Forest ecosystem vitality and health	Fire incidences Pest and diseases Invasive species
4. Conservation of soil and water resources	Forest types by protective functions Soil quality Quantity and quality of water supply Flood and soil erosion protection
5. Global carbon cycles	Carbon storage in biomass and soil
6. Multiple socio-economic benefits	
6.1 Livelihood opportunities	A proxy measure of food, shelter, clothing, etc. Timber, fuel, food, forage, fibers and medicines Value for eco-tourism Employment opportunities
6.2 Quality of human life	Value for drinking water, recreation value, human health status Value of water quality, air quality improvement
6.3 Cultural value	Cultural and religious value of forests
6.4 Equity	Upstream forest restoration versus downstream benefits Benefit distribution
6.5 Natural disaster	Human lives and property loss by floods, storms and cyclones
6.6 Land tenure security	Land tenure
7. Legal, institutional framework	Forest policies and legislation Environmental education

_ References

Ahn, Y. S., Ryu, S. R., Lim, J. H., Lee, C. H., Shin, J. H., Choi, W. I., Lee, B. D., Jeong, J. H., An, K. W., Seo, J. I. 2014. Effects of forest fires on forest ecosystems in eastern coastal areas of Korea and an overview of restoration projects. Landscape Ecol. Eng., 10: 229-237.

Ahn, Y. S. 2013. Effect of forest fires on Forest Ecosystem in Eastern Coastal Areas of Korea and Overview of Restoration Projects. *In*: Proceedings of the International Symposium on Commemorating Establishment of the Pan-Asia Wild land Fire Network, October 24, Seoul, Korea, pp 171-172.

Bae, J. S., Joo, R. W., Kim, Y. S. 2012. Forest Transition in South Korea: Reality, path and drivers. Land Use Policy, 29: 198-207.

Bae, J. S. 2007. Establishing process of the 10 year National Greening Project: at the turning point between the Government-oriented approach and administration-oriented approach. Journal of Korean Forest Society 96 (3): 269-282 (in Korean with English abstract).

Beatty, S. W., Owen, B. S. 2005. Incorporating disturbance into forest restoration. *In*: Stanturf, J. A, Madsen, P., eds. Restoration of Boreal and Temperate Forests. New York: United States. CRC Press, pp 61-76.

Bowers, K. 2013. IUCN's Forest Restoration Initiatives; Applying Lessons Learned for Restoring Mountain Forests. *In*: Proceedings of International Symposium on Mountain Ridge Connec tivity and Mountain Forest Landscape Conservation, Seoul, South Korea, pp 147.

Boyd, J., Wainger, L. 2002. Landscape indicators of ecosystem service benefits. Am. J. Agric. Econ., 84: 1371.

Brown, S., Sathaye, J., Cannell, M., Kauppi, P. 1996. 24. Management of Forests for Mitigation of Greenhouse Gas Emissions, *In:* R.T. Watson, M.C. Zinyowera, and R. H. Moss, Eds. Climate Change 1995 - Impacts, Adaptations and Mitigation of Climate Change: Scientific-Technical Analyses. Contribution of Working Group II to the Second Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), Cambridge University Press, Cambridge, U.K. pp 773.

Castaneda, F. 2000. Criteria and Indicators for sustainable forest management: International processes, current status and the way ahead. ftp://ftp.fao.org/docrep/fao/x8080e/x8080e06.pdf (accessed on 4 October, 2013. 09:45 a.m.).

Cho, D. H., Lee, K. J. 1995. A relationship between climatic factors and matsutake production in 29 sites during a 10 year period in Korea. Journal of Korean Forest Society, 84: 277 (in Korean).

Choi, W., Park, Y. S. 2012. Dispersal patterns of exotic forest pests in South Korea. Insect Science, 19: 535-548.

Choi, W. I. 2012. Major Forest Disease and Control Strategies in South Korea. Division of Forest Insect Pests and Diseases, Korea Forest Research Institute. http://www.kfri.go.kr

Choi, W. Y. 2010a. Forest Fire Disaster. Korea Forest Research Institute News 10-21. Division of Forest Disaster Management, pp 1-7.

Choi, W. Y. 2010b. Forest Soil Sediment Disaster. Korea Forest Research Institute News 10-19. Division of Forest Disaster Management, pp 1-7.

Choi, W. Y. 2010c. Combating Desertification. Korea Forest Research Institute News 10-23. Division of Forest Disaster Management, pp 1-7.

Chun, J. H. 2013. Management and Conservation of Mountain Forests in Korea. Korea Forest Research Institute. http://www.asiapacificadapt.net/adaptationforum2013/sites/default/files/Jung%20Hwa%20Chun.pdf. (accessed on 6 December, 2013. 11:00 a.m.).

Chung, D.J., Jeong, J. H., Choi, K. M., Kim, S. H., Song, Y. H. 2013. Analysis of Vegetation Type and Ecological Characteristics by National Forest Inventory Data. *In*: Proceedings of the International Symposium on Forest Health, 25 September. Seoul, Korea, pp 135-136.

Chung, Y. J., Bae, W. I., Yum, Y. C. 1987. Studies on the forecasting of major forest insects pest outbreak (II) prediction of the adult emergence of *Hyphantria cunea* D. Research Report of Forestry Research Institute in Korea, 34, pp 149-152 (in Korean with English summary).

Ciccarese, L., Brown, S., Schlamadinger, B. 2005. Carbon sequestration through restoration of temperate and boreal forests. *In*: Stanturf, J.A., Madsen, P., eds. Restoration of Boreal and Temperate Forests. Integrative Studies in Water Management and Land Development, pp 111-120.

Dixon, R. K., Brown, S., Houghton, R. A., Solomon, A. M., Trexler, M. C., Wisniewski, J.

1994. Carbon pools and flux of global forest ecosystems, Science, 263: 185.

Dudley, N. 2007. Impact of forest loss and degradation on biodiversity. *In*: Mansourian, S., Vallauri, D., Dudley, N. eds. Forest restoration in landscapes: beyond planting trees. Spring er, New York, USA, pp 17–21.

Dudley, N., Morrison, J., Aronson, J., Mansourian, S. 2005. Why Do We Need to Consider

Restoration in a Landscape Context? *In*: Mansourian, S., Vallauri, D., Dudley, N. eds. Forest restoration in landscapes: beyond planting trees. Springer, New York, USA, pp 51–58.

Dukes, J. S., Mooney, H. A. 1999. Does global changes increase the success of biological invader? Trends in Ecology and Evolution, 14: 135-139.

Fahey, T. J., Reiners, W. A. 1981. Fire in the forests of Maine and New Hampshire, B. Torrey Bot. Club, 8: 362.

FAO. 2010. Global forest resources assessment 2010- Forest Health and Vitality. FAO Forestry paper No. 163, Rome, Italy.

Farina, A. 2006. Principles and methods of landscape ecology. Springer, Dordrecht.

Forbes, K., Broadhead, J. 2007. The role of coastal forests in the mitigation of tsunami impacts. Bangkok (Thailand): Food and Agriculture Organization of the United Nations. RAP Publication 2007/1, pp 1-30.

Gomi, T. 2007. Seasonal adaptation of the fall webworm *Hyphantria cunea* (Drury) (Lepidoptera:Ar ctiidae) following its invasion of Japan. Ecological Research, 22: 855-861.

Gottfried, R., Wear, D., Lee, R. 1996. Institutional solutions to market failure on the landscape level. Ecol. Econ. 18: 33.

Han, H., Choi, W. I., Chung, Y. J. 2013. Major Insect Pests Threat to Forest Health in South Korea. *In*: Proceedings of the International Symposium on Forest Health, 25 September, Seoul, Korea, pp 113-130.

Hirai, K., Miura, S., Kaneko, S., Nagame, I. 2013. Indicator for soil protection – importance for forest health and long-term site productivity. *In*: Proceedings of the International Symposium on Forest Health, 25 September, Seoul, Korea, pp 91-112.

Ho, U. Y. 1975. An analytical study of the problems involved in the project to rehabilitate the illegal field burning cultivators in Gangwon Do. Jour. Korean For. Soc. 28: 50-66.

Incheon International Airport Corporation. 2000. 1992.11.5-2000.3.31 Incheon International Airport. Incheon International Airport Corporation, pp 233.

Jacobs, D. F. 2013. Optimizing seedling quality for reforestation after surface mining. Book of Abstracts. 5^{th} World Conference on Ecological Restoration, Reflection on the past, Directions for the future, October 6-11, Wisconsin, USA.

Jeong, J. H. 2013. Soil Classification in Korea. *In*: Proceedings of International Symposium on Forest Soil and Water Conservation, November 28, Seoul, Korea, pp 10-19.

Johnson, R. J., Magnusson, G., Mazzota, M. J., Opaluch, J. P. 2002. Combining economic and ecological indicators to prioritize salt marsh restoration actions. Am.J.Agri. Econ., 84: 1362.

Kauppi, P., Sedjo, R. 2001. 4. Technological and economic potential of options to enhance, maintain and manage biological carbon reservoirs and geo-engineering *In*: B. Metz, O. Davidson, R. Swart, and J. Pans, eds. Climate Change 2001. Mitigation, Contribution of Working Group III to the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), Cambridge University Press, Cambridge, U.K.

KFS [*Korea Forest Service*]. 2014. Map of Baekdu-Daegan Protected Area. Forest Geographic Information System. http://www.forest.go.kr/newkfsweb/html/PrintPage.do?mn=KFS_27_02_05

KFS [*Korea Forest Service*]. 2013. Statistical Yearbook of Forestry, No. 43. Korea Forest Service, Daejeon, South Korea, pp 486.

KFS [*Korea Forest Service*]. 2012a. Statistical Yearbook of Forestry, No. 42. Korea Forest Service, Daejeon, South Korea, pp 488.

KFS [*Korea Forest Service*]. 2012b. Sharing Experiences of Forest Rehabilitation, International

Cooperation Division, Korea Forest Service, Daejeon, South Korea, pp 1-6. http://english.forest.go.kr/newkfsweb/cop/bbs/selectBoardArticle.do?nttId=2838913&bbsId=BBSMSTR_1057&pageUnit=10&searchtitle=title&searchcont=&searchWrd=&ctgryLrcls=&ctgryMdcls=&ctgrySmcls=&ntcStartDt=&ntcEndDt=

KFS [*Korea Forest Service*]. 2011. Statistical Yearbook of Forestry, No. 41. Korea Forest Service, Daejeon, South Korea, pp 484.

KFS [*Korea Forest Service*]. 2010. Statistical Yearbook of Forestry, No. 40. Korea Forest Service, Daejeon, South Korea, pp 491.

KFS [*Korea Forest Service*]. 2009. Statistical Yearbook of Forestry, No. 39. Korea Forest Service, Daejeon, South Korea, pp 495.

KFS *[Korea Forest Service]*. 2008. Statistical Yearbook of Forestry, No. 38. Korea Forest Service, Daejeon, South Korea, pp 495.

KFS *[Korea Forest Service]*. 2007. Statistical Yearbook of Forestry, No. 37. Korea Forest Service, Daejeon, South Korea, pp 485.

KFS *[Korea Forest Service]*. 2006. Statistical Yearbook of Forestry, No. 36. Korea Forest Service, Daejeon, South Korea, pp 473.

KFS *[Korea Forest Service]*. 1993. Statistical Yearbook of Forestry, Korea Forest Service, Daejeon, South Korea, pp 528.

KFRI [*Korea Forest Research Institute*]. 2010a. Forest Eco-Atlas of Korea. National Records No. 11-1400377-000381-01, Research Note No. 384, pp 1-75.

KFRI *[Korea Forest Research Institute]*. 2010b. Post-Fire Restoration. To Establish a Healthy and Sustainable Forest Ecosystem. National Records No. 11-1400377-000393-01, pp 1-50.

Kim, M. N. 2013. Forest Fragmentation Analysis for Development Projects in Consideration of Forest Health. *In*: Proceedings of the International Symposium on Forest Health, 25 September. Seoul, Korea, pp 142.

Kim, Y. K., Lee, I. K., Lim, J. H., Chun, J. H., Shin, J. H. 2007. Designation of the Baekdu-Daegan Mountain System Protected Areas and its Management Strategies. *In*: Stanturf, J., editor. Proceedings of the IUFRO Conference on Forest Landscape Restoration. Seoul, Korea 14-19 May 2007, pp 90-91.

Kim, Y. K., Youn, H. J., Lee, I. K., Chun, J. H., Shin, J. H. 2010. Ecological Restoration and Management of Degraded Area for Baekdu-Daegan Conservation. *In:* Proceedings of XXIII IUFRO World Congress Forests for the Future: Sustaining Society and the Environment. International Forestry Review 12(5): 220.

Kim, Y. S. 2013. Soil GHG Fluxes in Changing Environment. *In*: Proceedings of the International Symposium on Forest Soil and Water Conservation. November, 28, Seoul, South Korea, pp 33-37.

Kim, Y. S., Byun, J. K., Kim, C., Kim, Y. K., Bae, S. W. 2013a. Needle Nutrient and Chlorophyll content of *Pinus densiflora* seedlings to different fertilizer compound ratio in a recently burned area. *In*: Proceedings of the International Symposium on Commemorating Establish ment of the Pan-Asia Wild land Fire Network, October 24, Seoul, Korea, pp 125.

Kim, J., Lim, J. H., Kwon, J., Bae, S. W. 2013b. Comparison on Early Growth of *Quercus mongolica* containerized seedling and *Quercus sp.* coppice at Burn Area in Samcheok, Korea. *In*: Proceedings of the International Symposium on Commemorating Establishment of the Pan-Asia Wild land Fire Network, October 24, Seoul, Korea, pp 150-151.

Kim, S., Jang, M., Abino, A. C., Lee, B., Lee, Y. 2013c. Crown Fuel Characteristics and Allometric Equation of *Pinus koraiensis* stands in Korea. *In*: Proceedings of the International Symposiu m on Commemorating Establishment of the Pan-Asia Wild land Fire Network, October 24, Seoul, Korea, pp 137-138.

Kim, Y.S., Lee, S. W., Cheong, J. H., Kim, Y. K., Bae, S. W. 2013d. Soil organic carbon storage in forest ecosystems using the 5th Korea National Forest Inventory data. *In*: Proceed ings of International Symposium on Forest Health, September 25, Seoul, South Korea, pp 144.

Kim, K. D., Lim, J. H., Kim, S. J., Kim, Y. K., Lee, J. Y. 2013e. Comparison of Purification Ability of Fast Growing Trees in Zinc Abandoned Mine. *In:* Proceedings of International Symposium on Forest Health, 25 September, Seoul, Korea, pp 137.

Kim, K. C., Lee, H. B. 1998. Natural enemies of black pine blast scale (*Matsucoccus thunbergianae*) in the black pine forests. Korean Journal of Applied Entomology, 37: 73-80 (in Korean with English summary).

Kim, Y. P. 1999. Transfer and restoration in the Ministry of Interior Affairs of Korea Forest Service. *In*: Half a Century Testimony for Agricultural Policy. Ministry of Agriculture and Forestry, Seoul, Korea, pp 415-431 (in Korean).

Kiritani, K., Morimoto, N. 2004. Invasive insect and nematode pests from North America. Global Environmental Research, 8: 75-88.

Kline, J. D., Alig, R. J., Johnson, R. L. 2000. Forest owner incentives to protect riparian habitat. Ecol. Econ. 33: 29.

KMA [*Korea Meteorological Administration*]. 2014. Climate of Korea. Korea Meteorological Adminis tration. http://web.kma.go.kr/eng/biz/climate_01.jsp

Koo, C. D., Bilek, E. M. 1998. Financial analysis of vegetation control for sustainable production of Songyi (*Tricholoma matsutake*) in Korea. Jour. Korean For. Soc. 87:519.

Koo J. W., Choi, J. K., Son, J. G. 1998. Soil properties of reclaimed tidal lands and tidelands of western sea coast in Korea. Journal of Korean Society of Soil Science and Fertilizer, 31(2): 120-127.

Kwon, T. S., Shin, J. H., Lim, J. H., Kim, Y. K., Lee, E. J. 2011. Management of pine wilt disease in Korea through preventive silvicultural control. For. Ecol. Manage. 261: 562-569.

Laarmann, D., Korjus, H. 2013. Initial effects of restoring natural forest structures in Estonia. Book of Abstracts. 5th World Conference on Ecological Restoration, Reflection on the past, Directions for the future, October 6-11, Wisconsin, USA.

Lee, B. Y., Chung, Y. J., Park, K. N., Byun, B. H., Bae, W. I. 1997. Distribution of pine needle gall midge (*Thecodiplosis japonensis*) Uchida et Inouye (Diptera: Cecidomyiidae) infestat ion in Korea: a brief history. FRI Journal of Forest Science, 56, 13-20 (in Korean with English summary).

Lee, C. Y. 2001. Traditional knowledge for soil erosion control in the Republic of Korea. Korea Forest Research Institute, No. 184, pp 110.

Lee C. Y. 1996. Foreste Environment Soil. Bosung, pp 48-75.

Lee, D. K., Suh, S. J. 2005. Forest restoration and rehabilitation in Republic of Korea. *In*: Stanturf, J. A, Madsen, P, eds. Restoration of Boreal and Temperate Forests. New York: United States. CRC Press, pp 569.

Lee, C. M., Kwon, T. S. 2013. Change of Ant Communities after forest fire. *In*: Proceedings of International Symposium on Commemorating Establishment of the Pan-Asia Wild land Fire Network, October 24, Seoul, Korea, pp 125.

Lee, D. K., Park, Y. D. 1999. Nitrogen Fixing Woody Plants in Korea. *In*: Proceedings of Korea-China International Joint Seminar on the Nutrient Cycling and Biomass Productivity in Forest Ecosystem, pp 6.

Lee, J. H. 1984. The Korean Model of Community Development- a case of Sae Ma Ul Undong. Journal of SNU Sae Ma Ul Studies, 4: 1.

Lee, K. S. 1995. Mechanisms of vegetation succession in abandoned fields after shifting cultivatio n in Chinbu, Kangwon-Do. PhD thesis. Seoul National University, Seoul, Korea.

Lee, K. 2002. Secondary Succession in Abandoned Fields after Shifting Cultivation in Kangwon-

Do, Korea. *In:* Lee, D., Jin, V., Choe, J. C., Son, Y., Yoo, S., Lee, H. Y, Hong, S. K., Ihm, B.S., eds. Ecology of Korea, Bumwoo Publishing Company, Seoul, Korea, pp 138-155.

Lee, W. C., Kim, C. J., Chon, S. K. 1979. Studies on secondary succession at early stage in deserted land of shifting cultivation in Gangwon-Do. Bulletin of the Korean Association for Conservation of Nature. 1: 145-166.

Liebhold, A. M., Tobin, P. C. 2008. Population ecology of insect invasions and their management. Annual Review of Entomology, 53: 387-408.

Lim, J. H., Kwon, J. O. 2013. Korea's Forest Landscapes Restoration Technologies. *In*: Proceedin gs of the International Workshop on Forest Landscape Restoration, 21 March 2013, Seoul, Republic of Korea, pp 89-108.

Lim, J. H., Shin, J. H. 2005. Forest vegetation shifts and plant phenological changes according to global warming. Nature Conservation 130: 8-17 (in Korean)

Mack, R. N., Simberloff, D., Lonsdale, W. N., Evans, H, Clout., M, Bazzaz, F. A. 2000. Biotic invasions: causes, epidemiology, global consequences, and control. Ecological Applications, 10: 689-710.

Maginnis, S., Jackson, W. 2007. What is FLR and how does it differ from current approaches?

In: Rietbergen-McCracken, J., Maginnis, S., Sarre, A. eds. The forest landscape restoration

Hand book. Earthscan, London, UK. pp 5–20.

Mansourian, S. 2005. Overview of forest restoration strategies and terms. *In*: Mansourian, S., Vallauri, D., Dudley, N., eds. Forest restoration in landscapes: beyond planting trees.

Springer, New York, USA, pp 8-16.

Mansourian, S.,Vallauri, D., Dudley, N., eds. 2005. (in cooperation with WWF International), Forest Restoration in Landscapes: Beyond Planting Trees, Springer, New York.

Mayers, N., Goreau, T. J. 1991. Tropical forests and the green house effect: a management response, Climate Change, 19: 215.

MIA [*Ministry of Interior Affairs*]. 1973. The First 10- year National Forestation Plan. MAI, Seoul, pp 76.

Miller, D. R., Park, S. C. 1987. A New Species of Matsucoccus (Homoptera: Coccoidae: Margarod idae) from Korea. Korean Journal of Plant Protection, 26: 49-62.

Nellemann, C., Corcoran, E. eds. 2010. Dead Planet, Living Planet – biodiversity and ecosystem restoration for sustainable development. A Rapid Response Assessment. United Nations Environment Programme, GRID-Arendal. www.grida.no.

Newton, A. C. 2010. Synthesis: Principles and Practice of Forest Landscape Restoration. *In*: Newton, A.C., Tejedor, N., eds. Principles and Practice of Forest Landscape Restoration. Case studies from the Dry lands of Latin America. Gland, Switzerland. IUCN XXVI, pp 383.

Newton, A. C., Tejedor, N. 2010., eds. Principles and Practice of Forest Landscape Restoration. Case studies from the Dry lands of Latin America. Gland, Switzerland. IUCN XXVI, pp 383.

Niklas, K. J., Spatz, H. C. 1999. Methods for calculating factors of safety for plant stems. Journal of Experimental Biology, 202: 3273-3280.

O' Hara, K. L., Waring, K. M. 2005. Forest restoration practices in the Pacific Northwest and California. *In*: Stanturf, J.A, Madsen, P., eds. Restoration of Boreal and Temperate Forests. New York: United States, CRC Press, pp 445-461.

Oliver, C. D., Larson, D. C. 1996. Forest Stand Dynamics, John Wiley & Sons, New York.

Park, J. W. 1998a. The Historical Implication of Forest Rehabilitation and Reforestation in Korea. *In*: Proceedings of Forest Ecosystem and Land use in Mountain Areas. IUFRO Inter-Divisional Seoul, 12-17 October 1998, Seoul, Korea, pp 3-5.

Park, K.S. 1998b. Change and Establishment of Gumsan-Bongsan System in the Chosun Dynasty, Korea Forest Research Institute, Journal of Forest Science, 57: 58 (in Korean)

Park, K. N., Miura, T., Hirashima, Y. 1985. Outbreaks History and present status of pine needle gall midge in Korea. Esakia, 23: 115-118.

Park, P. S. 2013. Wild land Fire Research in the Past and Wild land Fire Management in Recent Era. *In*: Proceedings of International Symposium on Commemorating Establishment of the Pan-Asia Wild land Fire Network, October 24, Seoul, Korea, pp 85-88.

Prime Minister's Office. 2011. Seamangum Master Plan, Republic of Korea, pp 10-50.

Saint-Laurent, C. 2011. The Bonn Challenge and Landscape Restoration. The Global Partnership on Forest Landscape Restoration Leaflet. Washington, United States.

Seo, J. I., Kim, Y. R., Kim, S. W., Chun, K.W. 2013. Jellyfish (*Nemopilema nomurai*) fertilizer contributes to the early establishment of seedlings planted in post-fire areas. *In*: Proceedings of International Symposium on Commemorating Establishment of the Pan-Asia Wild land Fire Network, October 24, Seoul, Korea, pp 133-134.

SER *[Society for Ecological Restoration]*. 2012. Annual Report. Society for Ecological Restoration 1017 O Street NW Washington D.C. 20001 USA, pp 1-15.

Shigesada, N., Kawasaki, K. 1997. Biological Invasions: Theory and Practice. Oxford University Press, Oxford, pp 224.

Shin, J. H. 2002. Ecosystem geography of Korea *In:* Lee, D., Jin, V., Choe, J. C., Son, Y., Yoo, S., Lee, H. Y, Hong, S. K., Ihm, B.S., eds. Ecology of Korea, Bumwoo Publishing Company, Seoul, Korea, pp 19-46.

Shin, J. H. 2007. Forest Damaged History and Future Directions for Forest Landscape Restoratio n in Korea. *In*: Stanturf, John., editor. Proceedings of the IUFRO Conference on Forest Landscape Restoration, Seoul, Korea 14-19 May 2007, pp 268.

Shin, M. H., Lim, J. H., Bae, S. W., Kong, W. S. 2013. Comparison of Growth and Distribution of *Pinus densiflora* in different sites after Goseong forest fires in Korea. *In*: Proceedings of International Symposium on Commemorating Establishment of the Pan-Asia Wild land Fire Network, October 24, Seoul, Korea, pp 154-155.

Shin, S. C., Choi, K. S., Choi, W. I., Chung, Y. J., Lee, S. G., Kim, C. S. 2008. An new illustrated Book of Forest Insect Pests. Upgo MunHwa, Seoul, pp 450 (in Korean).

Shuto, N. 1987. The effectiveness and limit of tsunami control forests. Coastal Engineering in Japan 30: 143-153.

Stanturf, J. A., Madsen, P. 2002. Restoration concepts for temperate and boreal forests of North America and Western Europe. Plant Biosystems, 136(2): 143–158.

Sung, J. H., Kim, S. H. 2013. Forest Health Monitoring in Korea. *In*: Proceedings of International Symposium on Forest Health, 25 September, Seoul, Korea, pp 28-41.

Thornburgh, D. A., Noss, R. F., Angelides, D. P., Olson, C. M., Euphrat, F., Welsh, Jr. H. H. 2000. Chapter 8. Managing Redwoods *In*: Noss, R.F. editor. The Red Wood Forest: History, Ecology and Conservation of the Coast Redwoods. Island Press, Washington, US, pp 229.

Togashi, K, Shigesada, N. 2006. Spread of the pinewood nematode vectored by the Japanese pine sawyer: modeling and analytical approaches. Population Ecology, 48: 271-283.

Wade, D. D., Brock, B. L., Brose, P. H., Grace, J. B., Hoch, G. A., Patterson, W. A. 2000. Chapter 4: Fire in eastern ecosystems. *In*: Brown, J. K., Smith, J. K. eds. Wild land Fire in Ecosystems: Effects of Fire on Flora. General Technical Report RMRS-GTR-42, Vol. 2, Ogden, UT, pp 53.

Wilpert, K. H. 2013. Functionality and Diversity of Forest Soils in South-West Germany: How to Preserve Them? *In*: Proceedings of International Symposium on Forest Soil and Water Conservation, November 28, Seoul, Korea. pp 3-5.

Won, M. 2013. The Strategies of Forest Fire Research in Korea *In*: Proceedings of International Symposium on Commemorating Establishment of the Pan-Asia Wild land Fire Network, October 24, Seoul, Korea, pp 20-37.

Yeom, C. H., Lee, S.Y., Kwon, C. G., Park, H. S. 2013. A recognition Analysis on Forest Fire Prevention Education for Residents in the SamCheok region. *In*: Proceedings of International Symposium on Commemorating Establishment of the Pan-Asia Wild land Fire Network, October 24, Seoul, Korea, pp 165-166.

Glossary of Forest Restoration Terms

Confusion reigns as the term restoration is used indiscriminately with no consensus even among practitioners in its meaning (Stanturf and Madsen, 2002; Mansourian, 2005). To clarify, below given are number of terms that have been defined recently by WWF and SER in its "The SER Primer on Ecological Restoration."

Ecological restoration	Ecological restoration is defined as the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed. It is an intentional activity that initiates or accelerates the recovery of an ecosystem with respect to its health, integrity, and sustainability.
Rehabilitation	Rehabilitation emphasizes the reparation of ecosystem processes, productivity, and services, whereas the goals of restoration also include the re-establishment of the pre-existing biotic integrity in terms of species' composition and community structure.
Reclamation	Reclamation is a term commonly used in the context of mined lands in North America and the United Kingdom. It has as its main objectives the stabilization of the terrain, assurance of public safety, aesthetic improvement, and usually a return of the land to what, within the regional context, is considered to be a useful purpose.
Afforestation / Reforestation	Afforestation and reforestation refer to the artificial establishment of trees, in the former case where no trees existed before.
Forest Landscape Restoration	Forest landscape restoration is "a planned process that aims to regain ecological integrity and enhance human well-being in deforested or degraded landscapes." It focuses on restoring forest functionality: that is the goods, services and ecological processes that forests can provide at the broader landscape level as opposed to solely promoting increased tree cover at a particular location.
Ecological integrity	It is defined as "maintaining the diversity and quality of ecosystems, and enhancing their capacity to adapt to change and provide the needs of future generations."
Human well-being	It is defined as "ensuring that all people have a role in shaping decisions that affect their ability to meet their needs, safeguard their livelihoods and realize their potential."
Landscape	It is a geographical space in which the process or object of interest is completely expressed or functions. It includes not only the biophysical components of an area but also social, political, psychological and institutional attributes.
Forest landscape	A landscape that is, or once was, dominated by forests and woodland and which continue to yield forest-related goods and services

_국립산림과학원 연구신서 목록

40. Tropical Trees of Indonesia. 2011.
41. 북악의 나무와 풀. 2011.
42. 한국 산림의 식물사회학적 분류. 2011.
43. 백두대간의 산줄기와 한민족의 삶. 2011.
44. 목조건축 시공표준. 2011.
45. 서해안 사구 자생식물 도감. 2011.
46. Glutathione의 분자생리학. 2011.
47. 포플러의 분자유전학. 2011.
48. Trees and Flowers in Bukak. 2011.
49. 중남미 주요목재의 식별. 2011.
50. 활엽수 병해 도감. 2011.
51. 황칠나무. 2011.
52. 상록활엽조경수 해충도감. 2011.
53. 기후변화, 숲 그리고 인간. 2012.
54. 경제수종 ③ 잣나무. 2012.
55. 경제수종 ④ 낙엽송. 2012.
56. 경제수종 ⑥ 백합나무. 2012.
57. 희망이 있는 아름다운 산촌마을 이야기. 2012.
58. Ecohydrology and Biogeochemistry in Korean Forest Catchment. 2012.
59. 경제수종 ① 소나무. 2012.
60. 경제수종 ② 참나무. 2012.
61. 경제수종 ⑤ 편백. 2012.
62. 조선시대 산불대책. 2012.
63. 한강과 함께하는 나무와 풀. 2012.
64. 금강과 함께하는 나무와 풀. 2012.
65. 낙동강과 함께하는 나무와 풀. 2012.
66. 영산강과 함께하는 나무와 풀. 2012.
67. 아라뱃길과 함께하는 나무와 풀. 2012.
68. 탄소지킴이 도시숲. 2012.
69. 홍릉숲길(가고싶고 걷고싶은 도심속 수목원). 2013.
70. 광릉숲 이야기. 2013.
71. 홍릉에서 바라본 숲 이야기. 2013.
72. 경제수종 자작나무. 2013.
73. Forest Landscape Restoration Success, Emerging Challenges and Future Direction in the Republic of Korea. 2014.

국립산림과학원 산림과학기술서비스헌장

우리 국립산림과학원 전 직원은 산림자원의 조성·이용과 환경이 조화된 임업기술을 개발하여 국민의 삶의 질을 높이고 우리의 고객인 국민에게 신뢰와 사랑을 받는 공무원이 되기 위하여 다음과 같이 실천하겠습니다.

하나. 산림은 우리 모두의 재산이며 생명의 원천이라는 인식 하에 국민의 삶의 질을 높일 수 있는 연구개발 및 기술보급에 최선의 노력을 다하겠습니다.

하나. 모든 서비스는 고객의 입장에서 생각하고 신속·정확·공정하게 처리하겠습니다.

하나. 국민에게 불친절한 자세와 잘못된 행정처리로 불만족이나 불편을 초래할 경우 즉시 시정함은 물론 적절한 보상을 해드리겠습니다.

하나. 우리의 실천노력에 대하여 고객에게 매년 평가를 받고 그 결과를 공개하겠습니다.

이와 같은 우리의 목표를 달성하기 위하여 ‘서비스 이행표준’을 제정하여 실천할 것을 약속드리며, 언제나 국민과 함께하는 국립산림과학원이 되도록 노력하겠습니다.

고객여러분께 부탁드리는 말씀

모든 고객께서는 친절하고 공정한 서비스를 받을 권리가 있으며 우리 산림공무원은 고객여러분께 고객만족과 감동의 서비스를 제공하기 위하여 이 헌장을 선포하고 실천해 나가고자 하오니 아낌없는 성원과 적극적인 협조를 부탁드립니다.

1. 불친절하거나 만족스럽지 못하였을 경우에는 즉시 알려주시고 반드시 성명·주소·연락처 등을 알려주시기 바랍니다.
2. 공무원이 자긍심을 갖고 열심히 일할 수 있도록 친절하고 모범이 되는 공무원은 적극 알려주시고 격려해 주시기 바랍니다.
3. 홍릉수목원과 산림과학관은 임업·임산업의 지식정보를 한자리에 전시한 대국민 교육의 장으로서 관람객의 편의제공을 위하여 예약실명제를 실시하고 있습니다.
   - 학술목적인 단체관람은 평일에만 가능하며
   - 관람예정 7일 전까지 예약하셔야 하며, 신청일로부터 30일 이후까지만 예약이 가능합니다.
   - 일반관람은 예약 없이 매주 토요일과 일요일에만 관람하실 수 있습니다.

의견제출·신고 또는 연락주실 곳

- **주 소** : ㊞130-712 서울특별시 동대문구 회기로 57(청량리2동 207번지)
- **팩 스** : (02)967-5101, 961-2525
- **전 화** : 원 장 실 (02)961-2500
연구지원과장실 (02)961-2511
민 원 실 (02)961-2522~3
- **인터넷** : http://www.kfri.go.kr
- 인터넷 홈페이지/전자민원창구/질의응답, 민원신고센터에 의견을 보내주시면 신속하고 정중하게 처리해 드리겠습니다.

연구신서 제73호

Forest Landscape Restoration Success, Emerging Challenges and Future Direction in the Republic of Korea

2014년 8월 인쇄
2014년 8월 발행

발행인 : 윤영균
집필 및 편집인 : 권진오, 마니람 목탄, 배상원, 임주훈

발 행 처 : 국립산림과학원
서울특별시 동대문구 회기로 57
Tel. 02-961-2635
Fax. 02-961-2649
인 쇄 처 : 경성문화사
Tel. 02-786-2999

ISBN 978-89-8176-274-2 (93520)

국립산림과학원
KOREA FOREST RESEARCH INSTITUTE

미션

MISSION

국민행복, 국토건강,
세계 녹화를 선도하는
산림과학기술의 개발과 보급

비전

MIND IDENTITY

“국민에게 사랑받는 글로벌 산림연구기관”

슬로건

BEHAVIOR IDENTITY

“살아있는 숲, 살리는 숲, 숲은 과학이다”

로고

VISUAL IDENTITY

“KFRI 플라워”

국립산림과학원
KOREA FOREST RESEARCH INSTITUTE

미션은 국립산림과학원의 고유임무 수행을 통해 국민의 삶의 질을 높이고,
국토를 안전하게 유지하며, 더 나아가
세계 산림을 풍요롭게 만들어 간다는 의지를 표명한 것입니다.

비전은 미션 수행을 통하여 2020년에 거듭날 기관의 미래상으로서
‘책임운영기관 고객만족평가 상위 5% 달성’, ‘세계5위권 산림연구기관’,
‘산림과학 지식 · 기술 2배 창출’의 의미를 담고 있습니다.

슬로건 ‘살아있는 숲, 살리는 숲, 숲은 과학이다’는 생명을 다루는
과학적이고 체계적인 연구자, 꿈을 이끌어가는 연구조직을 표방한 것입니다.

로고 ‘KFRI 플라워’는 연구의 꽃을 피운다는 의지를 상징하며,
불규칙해 보이지만 정교한 자연의 규칙성을 피보나치수열로 해석하여
자연과 조화하는 과학의 의미를 담고 있습니다.

새 옷을 입고 새로운 마음가짐으로
국민, 임업인, 산주 여러분께 감동을 주는 연구로 보답하겠습니다.

FOREST LANDSCAPE RESTORATION SUCCESS,
EMERGING CHALLENGES AND FUTURE DIRECTION
IN THE REPUBLIC OF KOREA

국립산림과학원
KOREA FOREST RESEARCH INSTITUTE

KOREA FOREST RESEARCH INSTITUTE
57-Hoegi-Ro, Dongdaemun-Gu, Seoul 130-712, Korea
TEL +82-2-961-2635 **FAX** +82-2-961-2649
e-mail alp96jk@forest.go.kr
http://www.kfri.go.kr

비매품
93520
9 788981 762742
ISBN 978-89-8176-274-2