

RECENT ADVANCE IN FORESTRY RESEARCH- AN OVERVIEW WITH REFERENCE TO INDIA

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ABSTRACT

Requirements of forest management need support of a research base, which is current and innovative. The traditional focus of forestry research which was Silviculture, Utilization and Economics catered to the commercial interests of forestry. Now with increasing demands for the social needs and the environmental services, there is a need for reorientation in research priorities. Forestry research has also been impacted by technological advancements in biotechnology and Information technology and has also developed interface with humanities. Global phenomena, such as, climate change, biodiversity conservation and invasive species have also impacted forestry research, as forests are considered a global resource. The paper reviews the impact of all these on forestry research, with special reference to India and lists the emerging disciplines, emphasizing on constant exchange of information and material between the managers of forests and forestry scientists.

INTRODUCTION

Effective and responsive forest management to meet the ever-changing requirements of the environment and the society needs the support of an efficient research base, which is current and innovative. The expectations from the forestry sector in the past were largely commercial and research was also accordingly focused on three main aspects: Silviculture, to know how the trees grow and how to make them grow better; Utilization, to make optimum use of the produce from the forests, and Economics, to make the Silviculture and Utilization economically viable, by assessment of demand and supply and fixation of price. Now the demands from the forestry sector are manifold, not confined only to the economic requirements, but also the social needs and environmental services. Forests are maintained not just for goods and products any more, but for the goods, products, services and values. The

Global Forestry Principle enunciated in the UNCED talks of scientific research which takes into account "biological, physical, social and economic variables, as well as technological development and its application in the field of sustainable forest management, conservation and development" (UN, 1992). The present day forester may not be in a position to gain expertise in all the diverse fields of forestry research, but it is important that he remains aware of the developments so that he can place his demands with the specialized agencies involved in research, to provide technical support to his management efforts.

FORESTRY RESEARCH IN THE PAST

Forest management in the colonial past was aimed mainly at consolidation of forests through various enactments and their conservation, besides utilization for various needs of development, such as, expansion of the railway network and telegraphic communication lines, structural uses and the needs

of war. The research was therefore, confined to development of suitable silvicultural systems to secure natural regeneration, and optimum tending operations, including thinning. On the utilization side, research was confined to forest mensuration, development of methods of logging and transport, saw-milling, wood preservation, seasoning and wood-working. In the post-independence period, a large number of wood-based industries were established and this increased the demand for wood. Further expansion of railway network needed a large quantity of sleepers. The development of the education sector demanded increased production of paper. The industrial requirements of wood and social requirement of fuelwood, necessitated raising of a large number of plantations. Once forests came to be raised by artificial regeneration, the principles applied to agriculture were applied to forestry also and this led to the efforts of domestication and breeding of forestry species. A large number of species introduction trials, provenance trials and progeny trials were laid throughout the country for many native as well as exotic species. Research was undertaken to breed high-yielding varieties through genetic combing, selection, breeding and production of quality seeds from seed orchards. This led to the development of seed science and technology, seed certification procedures, etc., as seeds were the product of breeding efforts. Besides efforts at genetic improvement of the species, research was undertaken to standardize the nursery practices and plantation management of a large number of species taken up for plantation programmes. Efforts were also made at vegetative propagation of many of the species for cloning but clonal plantations on a commercial scale remain confined to a few species, such as poplars, eucalypts and casuarina. Most of the research programmes in a majority of the forest departments remain developed only up to this stage. Many wood based industries have also undertaken research to support their programmes, especially the pulp and paper industries, plywood industries and match industries who are the major consumers of wood. Their research efforts are also largely confined to refinement of their product besides some efforts at tree improvement.

PRESENT DAY SOCIO-ECONOMIC NEEDS DEPENDENT ON FORESTRY RESEARCH

There is a growing demand for wood in the country. Forestry is impacted by sectors such as energy, agriculture, education, water resources, industry, infrastructure development, biofuels, change in demographic structure and high economic growth. India is a net importer of wood and wood products, to cater to the high growth being experienced by the economy. The infrastructural growth and housing demand large amount of structural timber. In construction industry, next to cement and steel, material used in large quantity is plywood, of which India is the largest producer in the world. Research is required to produce enough raw materials for the ply industries and also in improving the quality of plywood. With greater thrust on education, there is a growing demand for paper. The paper industry is chronically raw-material deficient, now depending to a large extent on agroforestry, agricultural waste and recycled paper to meet its requirements. Besides these two major wood-based industries, there are a large number of small-scale and cottage industries dependent on wood for manufacture of furniture, handicrafts, toys, veneers, safety matches, etc. (FAO, 2009).

The major demand for wood in rural areas and the temperate areas is firewood, for cooking and heating. This is also one of the major reasons for deforestation and degradation of forests. India is the largest producer as well as consumer of fuelwood. Nearly 75% wood that is extracted from the forests, ends up as fuel. Charcoal is another major produce, needed in the rural areas and specific industries, such as, tea processing. Research is needed to produce, wood of high calorific value and burning properties, as it is not possible to replace the requirement of wood with any other fuel, in the immediate future. Research on fuel-efficient gadgets to reduce the use of wood and charcoal is also needed.

Linked to the industrial use of forest produce, is the associated research on supply and demand of the produce, raw material requirement, national and international trade and understanding the economic and policy-making processes that affect the forests

and the forest produce. Research on such aspects will help the industries plan their production and supply, and also help the farmers plan their plantation programmes, thus eliminating collapse of market and loss to farm-foresters.

ENVIRONMENTAL DEMANDS ON FORESTRY RESEARCH

The forests are now valued more for their ecosystem services and biodiversity, than for the tangible economic requirements. This requires a better understanding of the basic biology and ecology of the forests. Information is required on the extent of biodiversity, ecosystem function and management, human-forest interactions, effects of climate change on forests, role of forests in climate change mitigation and maintenance of the health of the forests. This information can help in designing and implementing landscape level management plans. The implementation of the Convention on Biological diversity and the related national legislations requires documentation of the biological diversity and the associated traditional knowledge, which will again be an important area of research.

Climate change affects almost all disciplines of research and forestry is no exception. Trees are being studied for their mitigation potential. Associated with this is the generation of basic data required for carbon trading. Trees are also being studied for their adaptation to elevated levels of carbon-dioxide, elevated temperature and the associated changes in abiotic and biotic stress levels. As climate change can trigger a wave of invasive species, by making more and more areas favourable to them, studies have begun to identify methods of controlling and eliminating them. The carbon trading requires, exact measurement of carbon stock in different pools, and estimation of sequestration by various afforestation/ reforestation activities, which again requires research in carbon sequestration potential of various forestry activities.

Broadly, the climate change research can be categorized into (a) Climate change modeling, (b) mitigation research and (c) adaptation research. These include the following areas of research, related to forestry, which are relatively new:

(a). Climate change modeling

Development of regional models. The present climate predictions are based on global climate models. These are required at finer spatial resolutions for decisions at micro-level. Further, future scenarios of climate should include, besides the primary variables of temperature and precipitation, information on secondary variables like heating degree days, heat index, starting and ending days of seasonal monsoon rainfall, storm surge, etc.

GIS based framework for risk assessment: The natural hazards are likely to be aggravated by climate change. The physico-chemical stresses the plants face may intensify. The pest and disease spectrum will undergo changes. The sites of present distribution of the species may become unsuitable and newer areas may become favourable facilitating assisted migration of the species. All this information, if placed on a GIS platform will assist in taking appropriate decisions on spatio-temporal scale.

Socio-economic impact assessment. The society and the economy of the forest dependent and coastal communities are at stake due to the climate change. Impact assessment and modeling taking all relevant factors is essential to take the required measures for mitigation.

(b). Mitigation research

Integration of low-rainfall species into farming systems: In areas that are going to be adversely affected by drought, integration of tree species that are tolerant to drought in agroforestry systems will provide green cover as well as insurance in case of failure of agriculture.

Biomass for bio-energy production and composite wood products: Production of electricity using fossil fuels is one of major causes of emission of carbon dioxide. Production of electricity using woody biomass, will help in reducing the use of fossil fuels. The plantation that is cut for production of biomass can again be regenerated for sequestration of more carbon. Species suitable for high density plantation can be raised as energy plantations for providing the feedstock for power generation.

Quantification of impacts of management practices on soil carbon dynamics: Agronomic practices and irrigation have effect on the soil organic carbon status. These are required to be quantified in the agroforestry systems, for optimizing the management practices for efficient carbon sequestration in soils.

Development of improved models of sequestration: The present models of plantations and agroforestry systems need to be evaluated from the point of view of carbon sequestered, with a view to enhance the sequestration potential.

Role of forest products in mitigation: The use of timber in products that are maintained for longer durations, helps in fixation of carbon in durable form. The role of such products in mitigation needs to be quantified.

Development of methods for inclusion of wood products in carbon trading: Now the wood products are not considered for carbon trading, though they also lock up carbon in durable products for long periods. Methods have to be developed for inclusion of wood products in carbon trading.

(c). **Adaptation research**

Breeding new varieties with wider tolerance to climate variability: New varieties that are climate change ready, i.e., adapted to the changes foreseen with wider tolerance of climate variability have to be developed through conventional breeding or molecular breeding.

Breeding for increased tolerance to water stress, improved nutrient use efficiency: As water and nutrients are going to be the limiting factors in future, tree crops that are tolerant to water stress and having improved water use efficiency and nutrient use efficiency, are required to be bred.

Impact on pests and diseases: The pests and diseases may increase in intensity and distribution range. The plant- pest and plant- pathogen interactions may get either dampened or amplified under the changing climatic conditions. These have to be studied for appropriate response. Breeding for tolerance/ resistance to pests and diseases may also become necessary.

Interactive effects of increased carbon dioxide and water/ nutrient deficiency: The adverse effects of water and nutrient deficiency may get aggravated under conditions of elevated carbon dioxide and temperature. These interactive effects need further study.

Impacts on grazing, and weeds: The anticipated beneficial effects of elevated carbon levels on grassland productivity may increase the population of herbivores, which can pose a threat to the regeneration of forests. The weeds showing phenotypic plasticity may increase in their invasive potential and expand the range. These are required to be studied for appropriate remedial action.

IMPACT OF OTHER SCIENCES ON FORESTRY RESEARCH

The two major fields of research which have impacted forestry research are Biotechnology and Information Technology, including the Remote Sensing and Geographical Information System applications.

Biotechnology, which was well developed in agricultural sciences is now being applied to forestry on an increasing scale. Tissue culture which is the standard method for commercial propagation in horticulture and floriculture has now found a place in forestry also. Associated with this is the research on genetic engineering, to design trees of our choice and genomic research to unravel the genetic basis of the observed characters.

Information technology has revolutionized the way the information is collected, collated and processed for use. Bioinformatics provides an interface between Information Technology and Biotechnology, accelerating the efforts of genetic engineering. Ecoinformatics links ecological information with Information technology, to help the ecosystem managers to take informed decisions in management. The Remote Sensing techniques have made access to information at landscape level easy and timely for taking vital decisions in management of forests and protected areas. Incorporation of all the information on a Geographical Information System (GIS) platform

has speeded up the decision-making process and also made the decisions scientific and reasoned.

INTERFACE WITH HUMANITIES

Forestry research is no longer confined to forestry sector alone. The needs of the society and economic requirements have led to the development of Forest Sociology, Forest Economics, Ecological Economics, etc. Forests are no longer evaluated only on the basis of goods that are tangible. The forests are evaluated for all their contributions, both tangible and intangible, and their contribution to the local and global economy are also taken into consideration, leading to the emergence of the discipline of Forest Valuation. The environmental services are also treated at par with goods and Payment for Environmental Services (PES) is yet another emerging discipline. The extension of the forests into non-forest areas has led to agroforestry research aimed at identifying compatible combinations of trees and agricultural crop, resulting in increased productivity.

IMPACT OF GLOBAL PHENOMENA

Forestry no longer remains localized. Forests are seen as a global resource. The global phenomena like climate change, biodiversity conservation and invasive species have their impact on forestry and forestry research. Forests serve as carbon stock and also as source of carbon emissions when converted to non-forestry uses. They aid in mitigation by carbon sequestration. They reduce the use of fossil fuels, by being the source of biomass-energy. They also yield biofuels for transport and industrial uses, thus helping in reduction of carbon emissions. In future, plantations are going to play a major role, not only in meeting the requirement of wood, but also in mitigation of climate change. Climate change has also necessitated study of the adaptation of ecosystems, species and varieties to the change and also the effect of such changes on the forest types and the associated species. Biodiversity loss is a major threat looming over the globe, due to deforestation, land use change and consumerism. The urgent

need for documentation of available biodiversity, its conservation and sustainable use has opened up many fields of research. The loss of biodiversity due to invasive species has drawn attention of researchers to ways and means of controlling or eliminating the invasive species.

EMERGING FIELDS OF FORESTRY RESEARCH

In view of the impact of biotechnology and information technology on forestry research and also its interface with humanities and the global phenomena like climate change, biodiversity loss and invasives, the forestry research has diversified and specialized into many new areas of research. With increasing importance of plantations in meeting the requirements of the industries and the society, they are being more intensively managed than in the past. This has led to the emergence of the concept of "Precision Silviculture". The needs of environmental conservation and optimum utilization of resources have led to the emergence of practices like Integrated Pest and Disease Management and Integrated Water and Nutrient management. The nutrients are now being made available through use of beneficial microorganisms, helping in nitrogen fixation, phosphorus mobilization and overall growth promotion. These concepts once practised in agriculture have now become a subject of research in forestry. The development of plantation forestry has led to development of varieties as in agriculture, including improved seed sources and clones. This has necessitated varietal testing and registration to protect the Intellectual Property Rights. Consequently research is on for testing the varieties and ways of describing them to make them distinguishable in the field. To increase the productivity of plantations, studies are being undertaken in nutrient cycling and nutrient budgeting.

Solid Wood is no longer the only product of forests or plantations. To optimize the use of wood and to avoid wastage, research is on in the field of reconstituted wood, plywood, wood alternatives, particle boards, etc. To ensure that the management of forests and plantations is ecologically sustainable, research is being undertaken to evolve suitable

Criteria and Indicators (C&I) for Sustainable Forest Management (SFM). Logging is also being intensively studied to evolve Reduced Impact Logging (RIL). Forest Certification procedures are being evolved, to regulate the use of wood and to ensure that the product is from a sustainably managed forest or plantation.

As stated earlier, the impact of biotechnology has led to the emergence of novel areas of research in genetic engineering including gene isolation, genetic transformation, use of molecular markers, marker-

the emerging fields would be akin to building a superstructure without foundation. Equal emphasis is required on both the segments, for a balanced progress in forestry research.

assisted selection, etc. Information Technology has led to the emergence of disciplines like Bioinformatics and Ecoinformatics. Remote sensing and GIS applications have changed the way the forests are surveyed, inventorized and mapped.

A comparative table showing the thrust areas of forestry research in the past, which really laid the foundation of forestry research, and the new emerging fields which are the requirements of the present, is presented below. The emerging fields are not to be seen in isolation, as they have their roots in the foundation laid in the past. Concentrating only on

	Thrust areas of the past- the foundation of forestry research	Needs of the present- the emerging fields of forestry research
Basic research in forestry	Forest botany, mainly of timber species	Biology of forest organisms
	Forest zoology, mainly of large animals and birds	Biodiversity assessment and monitoring (Genetic diversity/ Species diversity/ Ecosystem diversity)
		Bioprospecting
		Ecosystem function, health and management
Silviculture	Growth and yield estimation	Sustainable forest management- Development of Criteria and Indicators
	Spacing and thinning trials	Precision silviculture- for production forestry
	Natural regeneration	Reclamation of degraded forests and wastelands- Restoration forestry
	Artificial regeneration	Research on forest fire, weeds, invasives, pests and diseases –Protection forestry
	Species introduction trials	Forest Genetic Resource management
	Tree improvement	Tree Breeding- conventional and non-conventional (genetic engineering)
		Clonal forestry
		Agroforestry
		Urban forestry
Utilization	Forest mensuration	Research on reconstituted wood- Fibreboards, plywood

	Forest logging (including planning, road alignment, machinery, etc)	Utilization of bamboo and cane
	Forest products research	Use of wood for production of energy
	Saw milling and wood working	Use of plantation grown timber
	Timber seasoning and treatment	High value special products- wooden pellets, activated charcoal, etc.
	Minor Forest Produce research (lac, resins, gums, fibre, fruits, etc.)	Reduced Impact Logging
Economics	Demand and Supply of wood and MFP	Forest certification- related to international trade in timber and wood-products
		Green economy
		Payment for Environmental Services (PES)
		Forest valuation- goods, products, services, recreation, tourism and aesthetics
		International trade in timber- policy analysis, market studies and pricing
		Carbon trading
Emerging fields		Use of GIS and Remote sensing in forestry- for planning and monitoring, resource analysis
		Bioinformatics and Ecoinformatics
		Forest biotechnology
		Climate change research (Modelling, Mitigation and Adaptation)
		Human- forest interactions
		Forest hydrology and watershed management

CONCLUSION

Though many of the emerging areas of research may appear remotely connected to forestry in the field and without any immediate practical application to a practicing forester, these disciplines have emerged basically from the original fields of research, namely Silviculture, Utilization and Economics. Without

a basic understanding of these disciplines and the requirements of forest management in the field, the emerging fields will not be in a position to draw inputs from the forests and forestry sector. Information technology can only ease the process of accessing information, but information has to be generated only by hard work in the field. Tree breeding, Clonal forestry and Genetic engineering can revolutionize

the plantation programmes by providing high yielding varieties, but the basic genetic material and its variations have to be tapped only from the natural forests, which are the repositories of biodiversity. The application of modern principles of economics and sociology has only helped in better understanding of the relations that already existed.

Thus there is a need for the practicing forester to keep his knowledge abreast to know where forestry is heading and how the new fields of research can contribute to better management of the forests. It is also equally important for the scientists working on these disciplines to know the way the forests are being managed, with all socio-economic ramifications and ecological impacts, so that they can fine-tune their research to meet the requirements of managers. There has to be a constant exchange of information

and material between these emerging fields of forestry research in the laboratories and the forest management in the field as both of them draw strength from each other.

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