CSWCRTI Vision 2030

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218, Kaulagarh Road, Dehradun, Uttarakhand (INDIA)
www.cswcrtiweb.org

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Central Soil and Water Conservation Research and Training Institute
218, Kaulagarh Road, Dehradun - 248 195, Uttarakhand, India
Tel. No. : 91-135-2758564
Telegram : SOILCONS
Fax : 91-135-2754213
E-mail : director@cswcrtiddn.org
Website : www.cswcrtiweb.org

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Dr. V.N. Sharda
Director

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Dr. Pradeep Dogra

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डॉ. एस. अय्यप्पन
सचिव एवं महानिदेशक
Dr. S. AYYAPPAN
SECRETARY & DIRECTOR-GENERAL

भारत सरकार
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कृषि मंत्रालय, कृषि भवन, नई दिल्ली 110 114

GOVERNMENT OF INDIA
DEPARTMENT OF AGRICULTURAL RESEARCH & EDUCATION
AND
INDIAN COUNCIL OF AGRICULTURAL RESEARCH
MINISTRY OF AGRICULTURE,
KRISHI BHAWAN, NEW DELHI 110 114
Tel.: 91-11-23382629, Fax : 91-11-23384773
E-mail : ayyappans@icar.org.in

Foreword

The diverse challenges and constraints as growing population, increasing food, feed and fodder needs, natural resource degradation, climate change, new parasites, slow growth in farm income and new global trade regulations demand a paradigm shift in formulating and implementing the agricultural research programmes. The emerging scenario necessitates the institutions of ICAR to have perspective vision which could be translated through proactive, novel and innovative research approach based on cutting edge science. In this endeavour, all of the institutions of ICAR, have revised and prepared respective Vision-2030 documents highlighting the issues and strategies relevant for the next twenty years.

Indian agriculture has been experiencing several challenging situations due to tremendous pressure being exerted on our limited natural resources especially soil and water. Conservation planning now needs to be based on the erosion risks computed by comparing the prevailing and the permissible erosion rates in a given location. Soil erosion above the tolerance limit leads to degeneration of soil reserves and soil fertility. Rainfed areas experiencing higher production and monetary losses need to be given high priority in terms of development of suitable conservation measures and their effective dissemination to substantially increase production on arable and non-arable lands.

Central Soil and Water Conservation Research & Training Institute (CSWCRTI), Dehradun has to retune and reorient the research endeavours to develop strategies and technologies to minimize erosion hazards, sustain productivity and improve socio-economic conditions of farming community by adopting participatory integrated watershed management approach.

It is expected that the analytical approach and forward looking concepts presented in the *'CSWCRTI Vision 2030'* document will prove useful for the researchers, policymakers, and stakeholders to address the future challenges for growth and development of the agricultural sector and ensure food and income security with a human touch.

(S. Ayyappan)

June 30, 2011
New Delhi

Preface

The challenge of realizing two divergent objectives of meeting the food demand of our country's ever growing population on one hand, and sustaining its limited and non-renewable natural resources for future generations on the other is growing steadily over the years. More so, the National Agriculture Policy of India envisages a growth rate of 4% per annum in agriculture sector to achieve a target of 345 million tonnes of foodgrain production by the year 2030. Fast degradation of our finite land and water resources is resulting in loss of food, fodder, fibre, and fuelwood production potential within the country, affecting livelihood and environmental securities of millions of people. Soil erosion by water is the most serious form of land degradation, resulting in loss of crop productivity, which has direct bearing on food security of the country. Notwithstanding the success achieved on food front in India during the last few decades, the complex problems of food security, poverty, equity and sustainability of resources need to be suitably addressed by agriculturists and conservationists in the current century.

The Central Soil and Water Conservation Research and Training Institute (CSWCRTI), with the primary mandate of conservation of natural resources dovetailed with optimal production from arable as well as non-arable lands, is a premier Institute of the Indian Council of Agricultural Research (ICAR), which has over 55 years of experience in developing strategies for checking land degradation and improving productivity of all primary production systems on sustainable basis. It has developed a large number of technologies that have been developed and successfully demonstrated in different regions through a network of eight Regional Centres in the country with headquarters at Dehradun. Multi-disciplinary research agenda not only focuses on realizing higher productivity and ensuring food security, but also on maintaining, rather enhancing quality of natural resource base. The Institute also conducts capacity building courses for policy makers, NGOs, field functionaries and farmers in soil conservation and watershed management.

The Institute has done pioneering work in evolving and popularizing the concept of integrated participatory watershed management along with new paradigms of transparency, equity and equitable distribution of benefits and resources in the country. Benefits of resource conservation and management, where ever undertaken on watershed basis, with due emphasis on social fencing, role of local community based organizations and peoples' participation, have substantially enhanced the productivity, moderated floods and mitigated droughts, augmented ground water recharge, generated employment and improved socio-economic conditions of stakeholders. The watershed approach is now being recognized in India as a main driving force to ensure natural resource conservation and management to alleviate poverty in traditionally resource poor and economically backward regions.

Since the problems of natural resources management are enormous and the task of raising productivity and production of food, fodder, fuel and fibre from our finite resources for meeting the ever increasing demand of the burgeoning human and livestock populations is gigantic, it calls for anticipatory, strategic and proactive research to conserve resources and enhance productivity of various land use systems in the country. Rainfed areas account for 68% of India's net cultivated land and support about 360 million people, which may rise to 650 million by 2030. Even after the realization of India's full irrigation potential by 2013, it is estimated that around 40% of India's net cultivable area of 142 million ha will remain rainfed. In the light of limited scope of increasing production from the irrigated sector, transforming rainfed farming into more sustainable and productive system through efficient use of natural resources provides the only viable alternative to the problem, which can be achieved through cutting-edge and socially acceptable conservation and production technologies, well supported by appropriate and forward looking agricultural policies for promoting all round development of agriculture sector. It is in this context that a perspective with a visionary approach is necessitated.

The first systematic effort to redefine strategies to bridge the existing gaps and address the emerging challenges was undertaken in 1997 by preparing '*Vision 2020*'. A subsequent attempt was made after five years by preparing '*Perspective Plan: Vision 2025*' to address the fast changing global and national scenarios in agriculture sector. The present document '*CSWCRTI Vision 2030*' articulates perceived challenges in Indian agriculture in the next two decades, and effectively tackle them through redefined strategic research endeavours, to provide new opportunities by harnessing the power of science.

I am highly indebted to Dr. S. Ayyappan, Secretary, DARE and Director-General, ICAR, New Delhi for his foresight, valuable guidance and consistent encouragement for developing this vision document. I express my gratitude to Dr. A.K. Singh, Deputy Director General (NRM), ICAR, New Delhi for his sincere advice and valuable suggestions in crystallizing approaches and strategies to face challenges emerging out of changing agricultural scenario. Sincere thanks are also due to all Heads of Divisions and Centres, and scientists of CSWCRTI for bringing out this document in the present form within the stipulated period. Scientists and staff of PME Cell deserve special thanks for efficiently compiling this document and bringing it out in a time bound manner.

June 30, 2011
Dehradun

(V.N. SHARDA)
Director, CSWCRTI

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Preamble

Food is the foremost requirement for survival of mankind, besides two other basic needs of clothing and shelter. It depends solely upon natural resources of land, water and vegetation, which need to be judiciously managed to meet the growing needs of burgeoning population. However, fast degradation of the land resource in our country through a complex interaction of natural processes and/or human activities is resulting in loss of its biological and/or economic productivity, thus affecting livelihood and environmental securities of millions of people.

Sustainability of land and other natural resources is under serious threat due to several degrading factors such as deforestation, shifting cultivation, conversion of prime forest land into agriculture, exploitation of fragile and marginal lands, and faulty agricultural practices. As per latest harmonized area statistics of degraded/waste lands in India, about 120.72 million ha is degraded, mainly due to water erosion (82.57 million ha). Among the negative impacts of soil erosion by water, loss in crop productivity, disruption of nutrient cycle, alteration in water and energy balances, pollution of water bodies, deterioration in water quality, reduction of reservoir capacity, loss of biodiversity, and natural disasters like floods and droughts have a strong bearing on national food and environmental security.

Simultaneously, the demand for natural resources is progressively increasing. India presently supports world's 18% human population and 15% livestock population on world's 2.4% land mass and 4.2% fresh water, and the pressure on the finite resources is swelling due to ever increasing population. Rise in human population is linked to rise in demand for water, with agriculture being the major consumer. Per capita utilizable water for various purposes would decline, while the per capita water demand in different sectors will increase. Consequently, share of agriculture sector in the total water use may reduce from 78% at present to 72% in 2025 due to competing demands from other sectors. Per capita net sown area availability has declined below the prescribed threshold limit of 2.0 ha of unirrigated land or 1.0 ha of irrigated land required for a family of five to six members. Further, agricultural productivity has remained stagnant and India ranks low among nations in the Global Hunger Index. To ensure food security, the average productivity of all foodgrains needs to be more than doubled from current 1.75 t/ha to achieve the estimated production of food grains.

Managing soil and land resources, including the degraded ones, to meet the growing human and animal needs in terms of food, fibre, fodder, timber and fuel, therefore, is considered of paramount importance in the present context as well as of the future. Rainfed areas, which constitute about 61% of the gross cultivated area, contribute only 42% to the total food production, while 39% of the irrigated area accounts for 58% of total output to the national food basket. However, rainfed areas offer great potential for agricultural growth. The challenge before the Indian agriculture, therefore, is to transform rainfed farming into more sustainable and productive systems through efficient use of natural resources. For this, harnessing the potential of integrated farming systems, integrated nutrient management, and integrated water management needs to be undertaken from conservation point of view through location specific technologies, including socio-economic suitability, leading to wider adaptability. In addition to these, there are many other challenges, such as impacts of climate change that need to be turned into opportunities for securing sustainable agricultural growth in the country.

India was among the first few countries to have taken timely cognizance of the enormity of problems of soil erosion due to rainwater. Since the establishment of CSWCRTI as Soil Conservation Research, Demonstration and Training Centres during the 1950s in different problem areas of the country and their reorganization into the present set up of Central Soil and Water Conservation Research and Training Institute (CSWCRTI) in 1974, the R&D activities of the Institute and its Centres have continuously focused on evolving strategies of soil and water conservation on watershed basis. The principal mandate of the Institute is conservation of natural resources dovetailed with production from arable as well as non-arable lands. It envisions challenges that the agriculture sector is facing for ensuring food, livelihood and environmental securities. The first systematic effort was made in this direction by preparing '*Vision 2020*'; the next attempt was made after five years by preparing '*Perspective Plan: Vision 2025*' to address the challenges through in-depth understanding of the degradation problems.

'CSWCRTI Vision 2030' document articulates many key challenges of the next two decades and appropriate strategies to address them through a roadmap for conservation and management of soil and water resources of the country to achieve sustainable production by developing technologies for controlling land degradation and enhancing productivity on sustainable basis thereby ensuring food, environmental, economic and livelihood security to the agrarian communities of the country.

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Land and Water Resources Scenario

Fast degradation of land resource, one of the primary resources required for existence of life on Earth, through a complex combination of natural processes and / or mankind's social and management activities is resulting in loss of its biological and/or economic productivity, affecting food, livelihood and environmental securities of millions of people. Of the world's total land area of 13.5 billion ha, about 2 billion ha is degraded (UNEP, 1986). About 5-7 million ha of arable land of the world is lost annually through land degradation (FAO/UNEP, 1983). The quantum of land degraded every year would take several decades to undo / limit the damage being done. Most degraded tropical and sub-tropical eco-systems are typically characterized by rising populations, fast diminishing biological productivity and diversity, hydrologic instability, inadequate vegetative cover, rampant soil erosion and fertility depletion, coupled with scarcity of food, fuel wood and fodder.

During the recent global food crisis in 2008, Indian agriculture performed better than several of the developing countries, and food production has exhibited an increasing trend over the past decades. However, recently it has failed to keep pace with the rising food demand due to continuing population growth and rising per capita income. As a result, India ranks 66th in Global Hunger Index among 88 nations (Menon, Deolalikar and Bhaskar, 2009). There are projections that demand for foodgrains would increase from about 232 million tonnes in 2010-11 to 345 million tonnes in 2030. Hence in the next 20 years, production of foodgrains needs to be increased at the rate of about 5.5 million tonnes annually. The average productivity of all foodgrains needs to be more than doubled from the current level of 1.75 t/ha (DES, 2007) to produce the estimated 345 million tonnes of foodgrains from a maximum net sown area of 150 m ha in 2030. Also, a serious supply-demand imbalance is being caused by changing food preferences from cereals to vegetables, fresh fruits, milk and fish due to rising per capita income, which needs drastic modification in farming systems being practiced on our limited agricultural lands. The demand for such high-value commodities is increasing faster than for foodgrains. For most of the high-value food commodities, demand is expected to increase by more than 100% by 2030 over 2000. However, the country is unlikely to achieve the required foodgrain production in future due to various inhibiting factors, including production losses due to land degradation and mismanagement of natural resources.

Land degradation and soil erosion

In India, about 68.4% (82.57 million ha) of the total degraded lands (120.72 million ha) is degraded due to water erosion, followed by chemical degradation (24.68 million ha), wind erosion (12.40 million ha) and physical degradation (1.07 million ha) (Maji, 2007). As per an estimate by Central Soil & Water Conservation Research & Training Institute (CSWCRTI), Dehradun, about 5334 million tonnes (16.35 t ha^{-1}) of precious soil is lost annually, resulting into a loss of 5.37 to 8.4 million tonnes of nutrients, reduction in crop productivity by <5% to >50%, floods/droughts, reduction in reservoirs capacity (1% to 2% annually), and loss of biodiversity. Therefore, research and development need to focus on accurately assessing and mapping of erosion hazards, soil fertility etc. and prioritizing the erosion risk areas, as in depth assessment of the status of land degradation due to soil erosion by water can help in macro and micro-level planning of resource management activities at watershed, region and country level.

Production losses due to soil erosion

Among the various losses caused by land degradation, the loss in crop productivity is of great significance as it has direct impact on food security of the country. CSWCRTI has estimated that 27 major rainfed cereal (8), oilseed (10) and pulse (9) crops cultivated on alluvial, black and red soils in the country as a whole suffer a production loss @ 16%, which in actual physical terms works out to 13.4 million tonnes which in economic terms is equivalent to ₹ 162 billion, considering minimum support prices of 2008-09 (Sharda, Dogra and Chandra, 2010). Cereals contribute 66% to the total production loss followed by oilseeds (21%) and pulses (13%). There is now an urgency to minimize the production losses in rainfed areas of the country, as these losses can be enormous on cumulative basis to significantly affect the agrarian economy of the country over the years. They need to be minimized and brought within permissible limits, to prevent further decline in the productivity levels. The challenge is, therefore, to (i) innovate and test cost- effective location specific conservation technologies for different climatic, edaphic and physio-graphic conditions, to mitigate production losses, achieve production sustainability, and ensure environmental security from primary production systems, (ii) introduce and evaluate exotic / improved germplasm for resource conservation and enhanced productivity, (iii) efficiently manage natural resources through conservation agriculture, horticulture and agroforestry, and (iv) identify potential systems for carbon sequestration under different best management practices for rejuvenation of soil fertility through reclamation of degraded lands.

Shrinking land resources

India supports 18% of the world's population on only 2.4% of world's land mass and the pressure on the finite land resource is continuously mounting due to ever increasing population. During the past about five decades (1950-51 to 2004-2005), area under agriculture increased by 22.57 million ha, i.e. from 118.75 million ha to 141.32 million ha, while uncultivated area declined by 22.45 million ha i.e. from 49.45 million ha to 27 million ha, particularly during the Green Revolution era. Presently, the net sown area is 46.3%, which alongwith fallow land of 24.94 million ha accounts for 54.5% of total land use. Nearly 22.8% of total land is under forests and almost equal percentage (22.7%) is under non agriculture use, which includes 17.58 million ha of barren land. However, per capita availability of net sown area has declined from 0.33 ha in 1951 to 0.14 ha in 2001 (Das *et al*. 2005), which is below the prescribed threshold limit of 2.0 ha of un-irrigated land or 1.0 ha of irrigated land required for a family of five or six persons (ADB, 2007). Per capita land availability is expected to further decline to 0.09 ha by 2050 thus demanding higher food production from the country's shrinking natural resources. The average size of landholding declined from

2.30 ha in 1970-71 to 1.32 ha in 2000-01, and absolute number of operational holdings increased from about 70 million to 121 million. With this trend, the average land holding size would fall to 0.32 ha in 2030. Also, over the past 60 years area under current fallow has increased by 38% due to deterioration of land quality / soil health. Under such a scenario, productivity needs to be significantly improved by protecting existing agricultural land from degradation, and reclaiming degraded lands through appropriate conservation strategies. The research should focus upon (i) evolving such conservation-cum-production technologies that meet the needs of smallholders' agriculture so that the productivity and environmental sustainability of the limited land at disposal of the small landholders is ensured, and (ii) developing suitable integrated farming system (IFS) models to address landholding size related issues of smallholders such as profitability and risk of production loss, as well as provide a supply of diverse food items to the Indian market to satisfy the growing needs of the affluent Indian population.

Water scarcity

'Water shortage' has rapidly, in a span of a decade, changed into 'Water scarcity'. Water scarcity is the outcome of the ever growing population, which results into higher demand for water in agriculture, industrial and domestic sectors. It has been envisaged that nations of the world in future will not wage war for more land but for more water. The large Indian population is sustaining on only 4.2% of the world's fresh water resources, which are fixed as per natural hydrologic cycle. The per capita utilizable water for various purposes, which was 1326 cum and 1093 cum in 1991 and 2001, respectively would further decline to 808 cum by 2025, while the per capita water demand in different sectors will increase to 1113 cum. Consequently, share of agriculture sector in the total water use may reduce from 78% at present to 72% in 2025 and 68% in 2050 due to competing demands from domestic, industrial and energy sectors. Ground water, which is the major source of irrigation at present, is rapidly declining by about 1 m annually in the rice-wheat areas due to over-exploitation, leading to economic and ecological distress. During one decade (1994-2004), the percentage of over exploited blocks where ground water extraction exceeds ground water recharge, rose from 4% to 15%. Therefore, challenging goals of enhanced food production and agricultural growth will have to be met from declining availability of water resources for agriculture sector in the country, thus necessitating its efficient and optimal utilization. Research needs to focus on (i) harvesting more surface water as it is estimated that about 24 million ha-m of rainwater can be potentially harvested through small scale water harvesting structures in different rainfall zones of India, of which, about one-fourth can be harvested in zones receiving rainfall < 1000 mm/year. Additional yield of more than one tonne per ha has been realized under CSWCRTI's multi-location technology transfer projects through supplemental irrigations. In this way, an additional foodgrain production of about 60-65 million tonnes can be easily realized. Further, the harvested water can be judiciously used for multiple purposes by cycling and recycling for drinking, domestic, irrigation, livestock, fisheries etc. as well as by integrated farming systems (IFS) to optimize water productivity, (ii) augmenting ground water recharge, as it has higher efficiency (70-80%) against 38% for surface water irrigation systems (Planning Commission, 2008), (iii) conserving more soil moisture through identification of suitable *in-situ* moisture conservation practices and refinement of existing ones for different crops and fruits to make them farmer friendly, and (iv) producing more foodgrains with less water through ecologically sustainable cropping systems, efficient irrigation technologies and innovative cultivation methods.

Climate change hazard

In the future, climate change could spell disaster for India's agriculture and freshwater supplies. The fact that most of the country depends on freshwater sources amplifies the threat of global warming on our society. The temperature rise and extremes of weather along the coasts, would cause drastic changes in India's hydrologic cycle that would threaten water supplies as well as agriculture, which is the key source of livelihood for most of India's 1.2 billion people. Number of rainy days is likely to decrease along with a marginal increase of 7-10% in annual rainfall over the sub-continent by the year 2080, leading to high intensity storms. While monsoon rainfall over the country may increase by 10-15%, the winter rainfall is expected to decrease by 5-25%, and seasonal variability would be further compounded. For controlling increased erosion due to climate change, research needs to focus on redesigning the conservation structures such as bunds, trenches etc. to handle the excess runoff and soil loss. The inevitable runoff from the high intensity storms would require to be harvested by redesigning water harvesting structures for providing supplemental irrigation during the lean periods.

Rainfed areas - New areas of growth

Agricultural productivity has either stagnated or showing a declining trend. Under current practices, there is a limited scope for improving production in irrigated areas since their productivity has almost reached a plateau. To meet the growing food demand, rainfed areas require special attention, which only contribute 47% to the national food basket though they occupy 61% of the total cultivated area. Even after achieving the ultimate irrigation potential, nearly 40% of total cultivable area of the country would remain rainfed where availability of rainwater is a major limiting factor due to erratic weather / climatic conditions. All rainfed areas are not alike as there are regional variations in rainwater availability and other natural resources. However, rainfed areas hold a great promise for agricultural growth and have a comparative advantage for specific type of agricultural production. Their potential needs to be tapped through scientific and efficient management of natural resources, especially soil and water. Conservation agriculture, zero tillage, and micro-irrigation needs to be perfected for different agro-ecological regions. Efficient farming systems, composite farming, integrated crop management, integrated nutrient management, and integrated water management need to be dovetailed for wider adaptability for poverty alleviation, and ensuring food and environmental security in rainfed areas.

Potential of participatory integrated watershed management

The concept of watershed planning, development and management, which was evolved and demonstrated by the Institute in 1970's, has emerged as a new paradigm for efficient management of land, water and other natural resources following bottom up participatory approaches. The success of watershed management concept in flood and drought moderation, ground water augmentation, increased biomass production, employment generation and improvement in socio-economic conditions of the local community was amply demonstrated through several model watershed projects implemented by CSWCRTI from 1970 onward. The Institute did pioneering work in evolving and popularizing the concept of participatory integrated watershed management (PIWSM) in the country with due emphasis on social fencing, transparency, and equitable sharing of benefits and resources through community based organizations and peoples' participation.

The achievements of watershed management approach as evident from the success of model watersheds developed by the Institute opened up new vistas of rural development. Participatory integrated watershed development programmes like NWDPRA, IWDP and NAEP were undertaken during 1990's and previously launched rural development programmes such as RVPs & FPRs, WDPSCA, EAS, DPAP and DDP were converted to PIWSM approach since 1987 onwards. As a consequence, upto March 2007, 56.54 m ha has been treated in the country with an expenditure of ₹ 19,471 crores under various soil conservation and watershed development programmes of the Ministries and other agencies (Sharda *et al*., 2009). A recent analysis of 636 micro-watershed development programmes across India indicated that they provided multiple benefits in terms of enhancing income, generating rural employment, increasing crop yields, reducing runoff and soil loss, augmenting ground water recharge, and alleviating poverty. More model watershed development projects need to be executed in different agro-ecological regions of the country for wider adoption of conservation-cum-production technologies by the state development agencies to harvest the tremendous benefits, including mitigation of negative impacts of climatic changes.

Social complexities of participatory integrated watershed management

People's participation is now recognized all over the world as an essential component in watershed management since involvement of local stakeholders and communities at multiple scales and zones is considered to be imperative while addressing cross-ecosystem issues and interactions related to farming and natural resource conservation. From 1994 onwards, India's four decades old watershed management programme switched from externally driven, centrally controlled, target oriented and top-down approach to people-centric, bottom-up and demand driven approach. Challenge of conserving natural resources has resulted in production of many promising technologies and practices for making agriculture and natural resource management more sustainable. Most of these technologies, however, require investment by farmers, both individually on their own farms and collectively through groups or communities. In addition to the farming communities, there are other outside key stakeholders such as the project implementing government and non-government agencies, researchers, planners and policy makers that are critical for addressing the complex problems and challenges in multi-purpose, multi-scale, temporal and diverse watershed contexts. With so many complexities, there exists a gap between the project goals and the ground realities making it difficult to realize the full benefits. Due to locally controlled points of entry, direction of the participatory process gets usurped by powerful community factions. Depth and precision in understanding social aspects are all too often sacrificed to the participatory demands. The challenge is to integrate tangible and intangible results/outputs between stakeholders, especially those related to people's needs as the people spend a great deal of time in the participatory process.

Capacity building for future

Capacity building is an integral component of the Institute's activities. The Institute conducts capacity building courses of varying durations regularly for policy makers, NGOs, field functionaries and farmers in the field of soil conservation and watershed management. With its vast experience, the trainings are being organized in a networking mode with adequate curricula and training modules for different levels of stakeholders employing modern tools and procedures for better understanding of the concept or technologies. It has been organizing regular training courses of 22 weeks twice a year in soil and water conservation and watershed management for officers and graduate assistants from various state agencies and other countries since 1956. Till March 2011, a total of 2652 gazetted officers and 5547 assistants have been trained, including 40 foreign participants, through 127 and 162 courses, respectively. The Institute also conducts specialized tailor made short term training and sensitization courses for officers/officials sponsored by various agencies in India and abroad. Upto March, 2011, 206 short courses for officers training 3776 participants and 630 short courses for assistants training 17,416 personnel have been conducted, including 95 foreign participants. For improving the outputs and outcomes of the huge public funds being invested by the governments through its various flagship schemes for rural and natural resources development, many more of these stakeholders need to be trained through refined and updated training modules.

3

Research on Conservation of Soil and Water Resources

India was among the first few countries to have taken timely cognizance of the enormity of the soil erosion problems. Many policy interventions and legislations were enacted from time to time in different states to combat the processes of land degradation. In 1948, Damodar Valley Corporation Act was passed to moderate floods through integrated watershed management in the Damodar river catchment. Realizing the importance of soil and water conservation, the Government of India established a chain of Soil Conservation Research, Demonstration and Training Centres during the 1950s in different problem areas located at Jodhpur, Dehradun, Kota, Vasad, Agra, Chandigarh, Bellary, Udhagamandalam and Chatra (Nepal) under the Central Soil Conservation Board in the Ministry of Agriculture and Cooperation. Out of these, all Centres, except Centres at Jodhpur and Chatra (Nepal), were reorganized into the present set up of Central Soil and Water Conservation Research and Training Institute (CSWCRTI) on 1st April 1974 with its headquarters at Dehradun. Two new Centres at Datia (M.P.) and Koraput (Orissa) were added to this set up in 1986 and 1992, respectively. These nine Centres are located in seven agro-ecological regions to cater the location specific soil and water conservation problems of the country. The soil and water conservation technologies are being developed within the following mandate of the Institute:

MANDATE

- Undertake research and develop strategies for controlling land degradation under all primary production systems and rehabilitation of degraded lands in different agro-ecological zones of the country.
- Act as a repository of information on the status of soil degradation/soil and water conservation.
- Provide leadership and co-ordinate research network with State Agricultural Universities/Institutions/NGOs/State

Departments for developing location-specific technologies in the area of soil and water conservation.

- Act as a national and international centre for training in research methodologies and updated technology in soil and water conservation, watershed development and its management.
- Provide consultancy and collaborate with national and international institutions in the field of soil and water conservation.

In the past about 5 decades, the Institute has developed a number of resource conserving technologies, both for arable and non-arable lands, which have the potential to check land degradation, minimize soil erosion, preserve soil's fertility, sustain productivity in the long run, conserve *in-situ* rainwater, harvest and recycle inevitable runoff, mitigate droughts, moderate floods downstream, and ensure environmental security. They include agronomical, mechanical and biological measures, alternative land-use systems, techniques for mass erosion control and water harvesting, and integrated watershed management. R&D activities of the Institute have focused on evolving strategies for soil and water conservation on watershed basis, tackling special problems such as ravines, landslides, mine spoils and torrents, demonstration of technology for popularization and imparting training. Reclamation technologies for torrents, gullies, landslides, mine spoils, gravelly / bouldery soils, sloping lands, watershed restoration, runoff harvesting, alternate land uses, diversification, biodiversity (ecological successions), bioremediation, management of common property resources and community participation were amply demonstrated with fairly good degrees of successes.

Experimental watersheds equipped with monitoring devices for generating watershed-based protection and production technologies were set up in 1956. From 1974 onwards, the Institute pioneered in operationalizing the watershed concept through four famous Operational Research Projects at Sukhomajri (Haryana State), Nada (Chandigarh), Fakot (Tehri-Garhwal in U.K.), and G.R. Halli (Chitradurga, Karnataka State). With the experience gained from these watersheds, the ICAR launched 47 model watershed programmes in sixteen states in collaboration with State Agricultural

Universities and State Departments. Encouraged with the success of the model watersheds, the Ministries of Agriculture and Rural Development conceived a massive development programme covering several thousand watersheds for soil and water conservation and sustainable development. CSWCRTI has kept up the efforts for the transfer of technologies through training, demonstration, lab-to-land programme, farmers' fairs etc. Experience of the research has been made use of by the Ministries of Agriculture, Rural Development and Environment and Forests, and the Central and State departments in their development programmes. Success of the watershed management programme attracted many international agencies like World Bank, EEC, DANIDA and Swiss Development Corporation for collaboration and funding support.

Adoption of resource conserving technologies for efficient utilization of land, water, vegetation and human resources following bottom up integrated watershed management approach is the only solution to meet the ever increasing demand of foodgrains, fodder, fuelwood and fibre for the growing population. To usher in an era of evergreen revolution, the country is poised to improve the abysmally low productivity of the rainfed areas following watershed approach as the productivity of irrigated areas has almost reached a plateau. A recent analysis of 636 micro-watershed development programmes across India indicated that they provided multiple benefits in terms of enhancing income, generating rural employment, increasing crop yields, reducing runoff and soil loss, augmenting ground water recharge, and alleviating poverty.

In late nineties, under Integrated Wastelands Development Programme (IWDP) of Ministry of Rural Development (MoRD), Government of India, CSWCRTI developed six model watersheds located in six states representing different agro-ecological regions of the country following participatory approach. Under environmental benefits, runoff from the watersheds reduced by 9 to 24% and reduction in soil loss varied from 32% to 90% with an average of 72%. The Induced Watershed Eco-index showed 12% improvement indicating that additional watershed areas were rehabilitated through green bio-mass. Crop Productivity Index increased by 12 to 45% with overall increase of 28% in crop productivity. Crop Diversification Index (CDI) also increased by 6 to 79% in the watersheds with average increase of 22%. With higher CDI, the risk in farming was minimized. Cultivated Land Utilization Index also improved significantly (2 to 81%) with an average value of 27%. These programmes created additional mandays casual employment (average 17,004 mandays) during the project. The average annual family income increased by 8% to 106% with an overall increase of around 49%. These projects were found to be economically viable ventures having BCR more than 1.14 to 1.69.

Government of India has adopted integrated watershed management programmes as a vehicle for rural transformation, employment generation and sustained productivity with environmental security. The model watersheds developed by the Institute have shown that if proper watershed technology is transferred through a community empowered institutionalized mechanism; it can play a vital role in agricultural development and overall rural transformation of the country. These model watersheds have been recommended by MoRD to be replicated to other areas under IWDP scheme by the concerned state governments, *viz*; Punjab, Gujarat, Rajasthan, Madhya Pradesh, Orissa and Tamil Nadu, which are already following these programmes. The watershed management technology demonstrated through model watersheds has the potential to cover 75 m ha rainfed area in the country. It is estimated that even if 50% of the yield advantage potential from the model integrated WSM projects is realized in these areas, the country can produce 97.7 million tonnes rice equivalent higher production annually.

Thus, participatory integrated watershed management approach has the potential to generate gainful employment to a large section of estimated 200 million people by 2025 and bring significant reduction in income inequality within the watersheds by increasing income by 30 to 200 percent. This would help in uplifting 320 million people living below poverty line, increase their purchasing power and consequently eliminate malnutrition or undernourishment problems in rural India.

4

CSWCRTI Vision 2030

The Central Soil and Water Conservation Research and Training Institute has continuously strived hard for effective development and management of the country's precious soil and water resources through frontier research and imparting technical skills to manpower engaged in the field of soil and water conservation and watershed management.

Vision

Conservation and management of soil and water resources of the country for sustainable production.

Mission

To develop technologies for controlling land degradation and enhancing productivity on sustainable basis for ensuring food, environmental, economic and livelihood security of stakeholders.

Focus

To accomplish its vision and mission, Central Soil and Water Conservation Research and Training Institute will concentrate on the following:

- Assess in depth the status of land degradation due to soil erosion by water, the major cause of land degradation in the country, at watershed, region and country level by innovatively employing appropriate modern tools and procedures.
- Prioritize erosion risk areas for effective planning and implementation of conservation programmes.
- Innovate and test cost effective resource conservation technologies for increasing biomass production from all primary production systems on rainfed, marginal and degraded lands.

- Introduce and evaluate exotic / improved germplasm of crops and trees for rehabilitation of degraded lands, generating higher productivity, soil rejuvenation through carbon sequestration, and mitigating adverse effects of climate change.
- Assess water availability/yield at different scales and locations, as well as under different conservation practices and climate change effects, for water harvesting and its effective utilization leading to enhanced and sustainable production.
- Develop indicators, decision support systems, policies and institutional mechanisms for efficient planning, execution, monitoring and evaluation of watershed development programmes, including quantification of tangible and intangible benefits.
- Collaborate with national and international R&D institutions, including state development agencies, in multi-locational technology development, refinement and evaluation of projects for erosion appraisal, conservation planning, and capacity building of scientists in advanced tools and techniques.
- Provide training to the field functionaries in the area of soil and water conservation and watershed management through upgraded and tailor made training modules covering all categories of stakeholders, right from grass-root workers to policy planners in different states, organizations, and agencies for effective implementation of various government sponsored watershed development programmes in the country.
- Develop live models of watershed development projects for demonstrating doable soil and water conservation technologies in different agro-climatic, topographic and socio-economic settings, and strive for their wider dissemination to the end users through the concerned state agencies by employing appropriate methods.

5

Harnessing Science

New frontiers of research tools and procedures shall be seamlessly utilized in the field of conservation and management of natural resources of soil and water for improving productivity, enhancing input-use efficiency, innovating cost-effective technological solutions, minimizing risks and improving quality of natural resources. New mechanisms, tools, methods, techniques and approaches that promise better understanding of status and management of soil and water resources in the country for accelerating innovations in natural resources management, to provide effective institutional and policy support would be employed. All research efforts will leverage the potential of frontier sciences like Decision Support Systems, Artificial Intelligence, Information and Communication Technology, Remote Sensing, Geographic Information System and Global Positioning System. These frontier sciences and techniques would be well integrated with the on-going and future agricultural research endeavours for improving research efficiency, better targeting of technologies and also identifying production and marketing environments. Diverse interests of different stakeholders in the natural resource management would also be addresses and realized.

Potential of remote sensing and GIS techniques for erosion related mapping

Use of remote sensing and GIS techniques has led to certain advancements in inventorizing the database and characterization of erosion hazards, but their accuracy still remains questionable, especially in hilly watersheds. Erosion hazards mapped for Himalayan watersheds by digital data of IRS-D, LISS-III and geo-coded FCC-PAN + LISS-III was carried out through infrared reflectance of prevailing vegetation, which masks the effect of other reflectances. Average accuracy of erosion hazards mapped by remote sensing, employing index based method, was observed to be 85%. Hence, the index based classification method for erosion hazards mapping has proved to be more accurate than earlier classification systems. Since utilization of remote sensing, GIS and simulation models is still at infancy stage in erosion related mapping, with future launching of satellites that provide imagery of finer resolutions, their potential needs to be exploited for accurately assessing and mapping of erosion hazards, soil fertility status etc. Unique and inherent advantages that remote sensing data possess such as repetivity, synopticity, digital nature of data and availability of data of inaccessible areas need to be explored to generate accurate and reliable database.

Potential of soil erosion risk assessment

Soil loss tolerance limits for different agro-ecological regions of India, which varied from 2.5 to 12.5 t $ha^{-1}yr^{-1}$ against an assumed default value of 4.5 to 11.0 t ha^{-1} yr^{-1} in all the states of India, were estimated. Soil erosion risk depends upon the difference between the prevailing erosion rate and the permissible rate or soil loss tolerance limit. In an agrarian country like India, assessment of soil erosion risk is of paramount importance to preserve soil's productive potential and ensure sustainable land use. Delineation and prioritization of erosion risk areas need to be successfully employed for conservation planning at watershed, region or country level by identifying best management practices to bring the erosion losses within the tolerance limits. Adequate knowledge of intensity and distribution of soil erosion risk is needed by land managers and policy makers to check land degradation and efficiently plan various cost effective land based interventions. Identified local areas where degradation is being arrested and even reduced can play an important role in regional development by expanding laterally to increase adoption of promising farming systems, and vertically to improve policy making to support sustainable development.

Bio-engineering measures for conservation and productivity

Conservation technologies such as contour farming, tillage, mulching, vegetative barriers, crop geometry, inter cropping / mixed cropping etc. on 2-8% sloping lands have reduced runoff by 8-40% and soil loss by 6-35%. The corresponding increase in productivity was 3-28%. However, technology development process needs to be responsive to the ever changing needs of agriculture. Innovative farming practices, primarily comprising agro-forestry have tremendous scope of increasing productivity and conservation of natural resources in future through agri-silvicultural, agri-horticultural, and silvi-pastoral practices, which have been established to increase phyto-productivity from arable and non-arable lands. Conservation agriculture / horticulture technologies like organic farming, mulching, tillage, micro irrigation, fertigation and canopy management hold a great promise towards increasing productivity of crops and fruits, and they need to be evaluated in new micro-environments in different agro-climatic regions. Integrated nutrient and micro-irrigation systems need to be dovetailed with different farming practices for wider adaptability on watershed basis. Technologies related to soil erosion, alternate land use systems, diversification, biodiversity (ecological succession), vegetative barriers, bio-remediation and management of common property resources have been investigated, however their impact on sustainable production has to be fully realized under farmer's field conditions.

Rainfed areas, which constitute about 61% of the gross cultivated area, contribute only 42% to the total food production and support a large number of India's poor are among the most environmentally fragile lands. However, rainfed areas offer great potential for agricultural growth with efficient management of rainwater. In these less productive areas, strategies to get agriculture moving will typically have to be different from the Green Revolution model. The challenge before the Indian agriculture, therefore, is to transform rainfed farming into more sustainable and productive systems through efficient use of natural resources. This gigantic task can only be achieved by formulating and adopting technically sound, economically viable, environmentally non-degrading and socially acceptable technologies that use country's natural resources for promoting sustainable development of agriculture.

Potential systems for carbon sequestration

In the second phase of Green Revolution in India, a decline in the growth rate in respect of foodgrain productivity and factor productivity has been clearly observed all over the country. One of the main reasons for this paradigm shift is large-scale nutrient depletion under intensive agriculture due to inadequate and unbalanced use of nutrients resulting in nutrient mining and negative nutrient balance in the system, which is more pronounced on sloping lands. Declining soil organic matter in all the climatic regions causes soil degradation to a great extent. Identification of potential systems for carbon sequestration together with cost aspects under different best management practices for soil rejuvenation / soil quality requires urgent attention in natural resource management, especially in sloping lands. New stocks of crops and trees developed through modern genetic engineering techniques hold great promise under different agroforestry systems in the backdrop of global warming and climate change impacts. The carbon sequestration potential of agro forestry systems is estimated between 12 and 22.8 Mg ha^{-1} with the median value of 95 Mg ha^{-1}. Developing decision support tools for efficient input management would be essential along with effective bridging of information gaps (technology transfer system) and related policy changes for effective implementation of technologies.

Conservation planning for climate change

A major challenge in the coming decades is to mitigate the impacts of climate change, which otherwise could spell catastrophe for India's agriculture and freshwater supplies. The temperature rise would cause drastic changes in India's rain cycles that may threaten water supplies and agriculture, which is the key source of livelihood for most of India's 1.2 billion people. Number of rainy days is likely to decrease along with a marginal increase of 7-10% in annual rainfall over the sub-continent by the year 2080, leading to high intensity storms. While monsoon rainfall over the country may increase by 10-15%, the winter rainfall is expected to decrease by 5-25%, and seasonal variability will be accumulated making crop production unreliable and less productive. It is likely to reduce yields of most crops in the long run. For controlling increased erosion due to climate change, the size of the conservation engineering structures such as bunds, trenches etc. need to be increased to handle the additional runoff and soil loss. The inevitable runoff received through high intensity storms would have to be harvested by redesigning water harvesting structures for providing supplemental irrigation during the winter period. Agro-forestry and horticultural technologies have great potential towards contingency planning for drought mitigation in the backdrop of global warming and climate change in the coming decades. They would have to be suitably modified for addressing this emerging problem. Eco-restoration of degraded sites is essentially needed to prevent loss of biodiversity. The problem is aggravating further in view of anthropogenic processes and climate change impacts. Conservation of biodiversity is essential for restoration of degraded lands, and modern tools and techniques of remote sensing and GIS will facilitate the sustainable use of biological and natural resources in future.

Hydrology and watershed management technology

The productivity of agriculture is largely dependent on the efficient management and utilization of water resources following watershed approach. However, there are issues of refining and upscaling the available technologies from micro to macro scales across different agro-ecological regions by adding new dimensions of quality aspects and pollution related problems. Therefore, efforts are required to evaluate, monitor and address the problems on a regional basis. Potential of rainwater management and utilization through micro-irrigation and integrated farming systems, groundwater recharge, estimating runoff and soil loss on regional basis, assessment and monitoring water availability, impacts of resource conservation technologies and watershed development programmes, hydrological implications of upstream-downstream linkages of habitations, impacts of watershed development programmes on flow regimes and perenniality of streams and rivers, and development of nomographic solutions for stream bank protection structures needs to be studied further and suitably refined in different agro-ecological regions.

Decision support systems for sustainable land management practices

The farming community and the government play a major role in the management of natural resources at the watershed level. The multiple objectives of watershed management comprise of a combination of technologies, policies and programmes. Watershed management essentially aims at achieving the various objectives of the multi-stakeholders, which is often restricted by their inability to take an appropriate and timely decision. Thus, there is a need for developing a multi-objective decision support system for effective resource utilization and validation of outputs.

Quantification and valuation of intangible benefits and environmental externalities of ecosystem payment services

In planning and management context, quantification and valuation of benefits plays a pivotal role. It is used to help determine optimal management programs. It involves comparing benefits to costs to ensure that program elements yield a positive return and then comparing the estimated returns across different combinations of program elements to find the most beneficial combination. Quantification of intangible benefits accruing from the adoption of NRM technologies would help in justifying the expensive interventions adopted in a watershed. In the present approaches, the intangible benefits are largely ignored as tools and techniques to reliably and authentically quantify and valuate them are not available. To address these complex issues, an integrated assessment of tangible and intangible benefits is essentially required by evolving suitable techniques to quantify and valuate the intangible benefits by assigning appropriate weightage to the governing parameters.

Policy issues and institutional analysis

At present, appropriate attention to the issues of new trends in technology transfer and their implications on regional, national and international level policy formulations is not being given. Low level of technology adoption may result from lacunae in the government policies and laws, and poor information sharing amongst the stakeholders. It requires proper research attention so that there is an impact during the decision making process. The major focus should be to ensure that technology may be most effectively transferred from the policy planners right upto the farmers, and address all the barriers that affect its transfer. Policy advocacy for mandatory adoption of natural resources conservation measures in the areas that witness soil erosion losses beyond the permissible limits will have to be initiated at the state, regional and national levels. The percolation of policy changes at various levels of the executive only can strengthen the institutional mechanisms.

Women's empowerment and gender mainstreaming

Women constitute 32% of the agricultural workforce in the Indian sub-continent (Adhiguru & Ramasamy 2003), and this percentage is rising due to the migration of men to urban areas. Therefore, women play a major role in managing natural resources and ensuring food and nutritional security. They are, however, rarely involved in decision-making related to on farm food production due to social customs, economic dependence, and low education levels. There is an urgent need to reduce the drudgery from farm and household activities where the women contribute their might. Conservation of natural resources and increased water availability has the potential of lessening the toil of everyday farm and domestic chores through their involvement in the watershed management programmes. It is important to assess the extent of involvement of women in natural resources conservation, constraints restricting their participation, and recommending strategies for their increased participation.

Human resource development

A well-trained technical manpower is a pre-requisite for effective planning and execution of watershed development programmes. Well-informed farming community will adopt new technologies and strengthen the process of natural resources conservation along with increased productivity to meet the future challenges of food security. Thus, there is a strong need to build the capacity of all the stakeholders to facilitate the most efficient decision making leading to conservation of natural resources through the watershed approach. Recognizing this fact, the Government of India has kept a provision for training and capacity building to the tune of 5% of the total cost in all the centrally funded watershed development programmes. It is estimated that training needs would increase manifold in future necessitating organization of about 19000 short term training courses each year (25 persons per course) to train various categories of watershed functionaries, which include farmers/watershed committee members, members of project implementing agencies (PIAs) and watershed development teams (WDTs), district officers, state-level officers and policy planners by the end of the XIII Plan. Hence, capacity building of stakeholders involved with NRM from grass-root workers to policy planners will constitute important activity of the institute with emphasis on the current issues. This invariably would need concerted efforts in up-scaling the training facilities and infrastructure to provide quality training material and services.

Technology transfer, adoption and diffusion

The technologies developed by the Institute have to reach the end users, the farming community, at the appropriate time in order to reap the benefits and enable the multi-stakeholders to optimize returns from the adoption of sustainable land management practices. The potential conservation technologies are being transferred through various outreach programmes like development of model watersheds sponsored by Central Government Ministries and other agencies in the country under various schemes. Despite serious efforts, the level of technology adoption has always been a matter of grave concern. Factual analyses of technology adoption and the constraints prohibiting their wider dissemination need to be identified and analyzed.

6

Strategy and Framework

The following strategies would be adopted to accomplish the vision and goal of the Central Soil and Water Conservation Research and Training Institute and enhance the efficient utilization of natural resources for sustainable production (see Annexure).

Assess land degradation and erosion risks for conservation planning

- Apply remote sensing and GIS tools in soil erosion hazards and fertility mapping / spectral reflectance.
- Delineate and prioritize erosion risk areas for identifying best management practices to bring the erosion losses within the tolerance limits at watershed, region or country level.
- Undertake collaborative research and development projects involving R&D organization in different agro-ecological regions for erosion assessment and conservation planning.
- Capacity building of scientists and technical manpower for optimum utilization of advanced tools and techniques.

Develop appropriate cost effective resource conservation technologies and their up scaling for better technology adoption

- Develop conservation technologies and innovative farming practices, and test their efficacy for sustainable production under farmer's field conditions.
- Upscale existing agro-forestry systems in degraded lands by conducting multi-locational trials in different agro-ecological regions to generate location specific technologies.
- Focus on rainfed, marginal, fragile and degraded areas to check land degradation and their effective utilization.
- Formulate mission oriented, multi-objective, multi-locational technology developmental projects cutting across disciplines and institutions in different agro-ecological regions.

- Develop linkages with national and international R&D organizations / developmental agencies and other stakeholders for technology development, refinement and their adoption.

Introduce and evaluate exotic / improved germplasm for resource conservation and productivity

- Characterize new varieties of major crops, traditional crops, fruits, vegetables, spices, medicinal and aromatic plants, and elite provenances of multipurpose trees for resource conservation in different agro-climatic regions.
- Identify potential low cost systems for carbon sequestration under different best management practices for soil rejuvenation / soil quality improvement.
- Identify suitable fruits, trees and grasses to address the issues of climate change impacts and sustained productivity.
- Assess efficacy of buffer strips, vegetative barriers or strips for improving the water quality parameters and check erosion in the different agro-ecological zones.
- Introduce "high value low volume" fruits, vegetables, spices and plantation crops for sustainable production with high economic returns in different agro- ecological regions.

Manage natural resources through conservation horticulture and agroforestry

- Integrate and evaluate mulching and micro-irrigation systems for fruits and vegetables under different agro-climatic regions.
- Enhance nutrient use efficiency through integrated use of organic manures and fertilizers for resource conservation and sustained productivity.
- Refine architectural management practices like canopy and root management by pruning and training in established plantations for enhanced biomass production, nutrient cycling and water yield.

Mitigate impacts of biotic interferences through forest vegetation management

- Study effect of forest composition and biotic interferences on natural resources conservation.
- Exploit biodiversity for eco-restoration of degraded areas with consideration of its carbon sequestration potential.
- Identify and evaluate drought hardy species as well as modify planting techniques for improving production from class IV to VII lands in drought prone areas.

Assess water yield potential at micro and macro watershed scales for production in different regions

- Assess water availability and upstream - downstream linkages at micro and macro watershed scales employing modern tools and procedures as an impact of watershed management programmes.
- Assess rainwater storage potential in different terrain conditions and improve rain water harvesting technology for prolonged storage, especially in the light of climate change impacts.
- Evolve manipulation strategies for balanced and sustained water yield from small watersheds.
- Develop and demonstrate location specific integrated farming systems (IFS) with multiple use of available water.

Socio-economic analysis and policy development for watershed management

- Develop user friendly Decision Support Systems for different situations at the farm and watershed level for planning, adoption of sustainable land management practices and their evaluation for optimizing resource utilization.
- Evolve suitable indicators/methodology for the quantification of intangible benefits and environmental externalities of ecosystem payment services through multi-disciplinary approach.
- Develop policies and institutional mechanisms based on the NRM research findings and feedback from the stakeholders

leading to advocacy for mandatory adoption of natural resources conservation measures.

Human resource development and technology transfer

- SWOT analysis for women's participation and develop mechanism for increasing the role of women in the decision making process in the WSM programmes and other outreach activities.
- Regularly up-grade training modules for natural resource conservation in different states of India ranging from grass-root workers to policy planners, organizations, and other agencies in consultation with the state government departments/agencies.
- Develop cost-effective tools/methods for effective transfer and adoption of technology using ICT in addition to the participatory research, OFTs and FLDs to strengthen the outreach programme. Refine technology transfer methodology along with strengthening of linkages with line departments and other agencies for funding and effective technology transfer.

Epilogue

The Central Soil and Water Conservation Research and Training Institute is committed to the development of modern resource conserving technologies for effective development and management of our precious natural resources through research endeavours to achieve targeted production levels in future. Development of technically sound, economically viable, environmentally non-degrading and socially acceptable strategies for conservation, management and efficient utilization of country's land, water, vegetation, livestock and human resources to promote sustainable growth of agriculture would be the ultimate aim of future research endeavours.

Better assessment of soil erosion hazards through application of modern tools and prioritization of erosion risk areas at different scales would help in high precision planning of limited resources for significantly mitigating the adverse impacts of land degradation in the country. Formulation and refinement of well tested, farmer friendly and cost-effective location specific conservation technologies for rainfed arable and all non-arable lands based upon prevailing erosion risks in a given area, and upscaling them would go a long way in efficient management of our natural resources, which coupled with assessment of water availability at micro and macro watershed scales for its harvesting and judicious use, would provide required impetus to turnaround the existing slowdown in Indian agriculture. Screening, evaluation and introduction of germplasms, such as 'low volume high value crops', individually or in different combinations, for resource conservation and higher input use efficiency would provide multiple choices to agricultural entrepreneurs, leading to development of location specific integrated farming systems (IFS) models under different farming situations. Adoption of these viable IFS models will help in meeting the diversified food demands of our affluent population, while in turn providing higher economic returns to our marginal and small farmers. Developing cost-effective techniques for effective transfer and adoption of conservation-cum-production technologies following watershed approach along with strengthening of linkages with line departments and other agencies would provide the right platform for wider dissemination of the technologies. Employing decision making tools and identification of key indicators for watershed planning, monitoring and evaluation would act as a catalyst for increasing efficiency and impact of our hugely financed watershed development programmes being implemented through Central Ministries and other government and non-government organizations in the country.

The technologies being developed have the potential to meet the food demand of our country, and at the same time provide gainful employment and livelihood to the agrarian community as well as those engaged in allied agriculture sectors, besides providing relief to our stressed natural resources, to sustain our current and future generations.

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Annexure : Strategic framework

Goal	Approach	Performance measures
Appraise water erosion in different agro-ecological regions	• Make inventory / database and characterize land degradation and erosion hazards using high resolution remote sensing data and GIS techniques • Delineate and prioritize erosion risk areas for identifying best management practices. • Estimate erosion and productivity relationship under primary production systems in different agro-climatic regions • Develop cumulative rating/indices of land quality and site specific land suitability criteria for sustainable land use planning	• Data base on land degradation and erosion hazards • Land suitability and quality index criteria / indices • Impact of erosion on productivity
Conservation measures for sustainable production systems	• Evaluate technologies for resource conservation on arable and non- arable lands • Study organic farming for soil health, resource conservation and sustainable production • Identify, evaluate and refine diversified land use systems • Generate location specific technologies for rehabilitation of degraded areas • Develop location specific integrated farming system models for maximizing profit and minimize erosion hazards • Generate technological options for enhancing resource use efficiency • Up-scale refined / proven technologies for enhancing livelihood security • Identify carbon sequestration potential under different land uses and estimate cost of carbon sequestration for maximizing yields	• Conservation technologies and diversified land use options • Increased sustainability of land use systems through improved efficiency of resources • Improved environmental quality and mitigating climate change impacts • Evaluation of trial under different land use systems w.r.t. soil quality and sustainability • Better input use efficiency nutrient use efficiency • Better water use efficiency/ water productivity

Goal	Approach	Performance measures
	• Rejuvenate soils through balanced, IPNM and SSNM for sloping lands	
Sustainable land use management practices	• Evaluate new varieties/ provenances for different fruits and tree based agro-forestry systems • Introduce suitable medicinal and aromatic plants, spices, fruits, plantation crops, underground vegetables, etc. for different agro-climatic regions of the country with reference to weather aberrations	• Enhanced Productivity and resource conservation • Enhanced livelihood security through sustainable income
Develop sustainable agro forestry/ forestry practices on watershed basis	• Develop and refine agro-forestry systems (agri-horti, silvipasture, agri-silvipasture and sericulture) as alternative land use systems for degraded lands • Develop location specific integrated farming systems for enhanced production and livelihood security • Diversify agriculture for resources conservation and productivity enhancement	• Land quality improvement, production efficiency enhancement and socioeconomic development • Establishment of linkage between farm and industry/ established public private partnership model in agri-processing • Improved productivity of arable and non-arable lands
Study impact of forest vegetation and biotic disturbances on natural resources conservation for sustainable production	• Evaluate hydrological behaviour of trees / shrubs / fruit plants • Estimate effect of different management practices on hydrological behaviour of forest catchments	• Improved environmental quality and mitigating climate change impacts on sustenance of perennial streams and water bodies • Database on run off and soil loss under natural and manmade forests and other land use systems
Plan, monitor and evaluate micro-watersheds using remote sensing and GIS techniques	• Use high resolution satellite data for planning, monitoring and evaluation of micro-watersheds	• Quick and realistic planning/evaluation of micro-watersheds
Evaluate design specifications of trenches in different AERs	• Evaluate trenches constructed with recommended specifications/ practices for resource conservation aspects under field conditions	• Optimize trenching density as a resource conserving measure for erosion control and biomass production

Goal	Approach	Performance measures
Manage and utilize rainwater by employing appropriate water harvesting techniques in different regions	• Assess rainwater storage potential in different terrain conditions • Improve rain water harvesting technology for prolonged storage and mitigate climate change effects • Evolve manipulation strategies for balanced and sustained water yield from small watersheds • Develop and demonstrate location specific fishery based integrated farming systems • Undertake water budgeting in various agricultural sub-sectors	• Sustained water yield • Increased water productivity • Identification of best management practices for different regions • Farmer - friendly IFS models with enhanced yields, profit and optimal resource utilization
Assess water availability at micro and macro watershed scales employing modern tools and procedures	• Determine management options to improve and maintain water availability for agricultural land • Determine strategies for assessment of point and non-point sources of pollution from agricultural watersheds • Develop and apply software tools and techniques with hydrological features and functionalities for assessment of water availability in watershed and future scenario	• Improved management strategies for sustaining the productivity of agricultural lands • Guidelines to check the agricultural pollution reaching to the main stream • Decision making tools for implementation of Best Management Practices (BMPs) • Developed GIS data base inventory for watersheds
Assess upstream-downstream linkages at micro and macro scales for analyzing the impact of watershed interventions	• Study the hydrological behaviour of watersheds following a nested network approach on micro and macro scales • Study complementarities and conflicts in upstream-downstream linkages	• Better understanding of water availability and management in different toposequences • Improved understanding of perenniality of flow (surface / sub-surface) at different watershed scales
Develop design procedures and nomographic solutions for torrent training structures	• Refine design of torrent training structures at different scales based upon climatic and physiographic features of catchment areas	• Flood protection and land reclamation as a result of guided torrent flow

Goal	Approach	Performance measures
Develop and refine bio-engineering technologies for rehabilitation of different mined environments	• Standardize BMPs and evolve appropriate cost-effective bio-engineering solutions for different mined environments	• Greening of degraded mined lands with suitable vegetation measures
Rehabilitate landslide affected slopes	• Standardize BMPs and evolving bio-engineering measures for slope stabilization in different geo-hydrological situations	• Reclaimed lands for productive use and improvement in water quality
Develop human resources and transfer of technology	• Develop capacity of faculty through training and exposure visits • Undertake human resources development for watershed management • Transfer technology for adoption and diffusion • Empower women for gender mainstreaming	• Advanced knowledge in training tools and techniques • Improved skills and knowledge of multi - stakeholders • Increased levels of technology adoption • Improved socio-economic status
Undertake socio-economic analysis and develop policies for watershed management	• Develop decision support systems for sustainable land management practices • Study policy issues and undertake institutional analysis • Quantify and valuate intangible benefits and environmental externalities of ecosystem payment services	• Improved resource use efficiency • Strengthened institutionalized mechanisms and advocacy • Assessment of environmental value and benefits of conservation measures

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