SOUVENIR

INTERNATIONAL CONFERENCE

On

Sustainable Natural Resource Management under Global Climate Change

November 07 -10 , 2023
New Delhi, India

Organized by

Soil Conservation Society of India, New Delhi

In collaboration with

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ICAR - Indian Agricultural Research Institute, India
National Academy of Agricultural Sciences, India
International Soil Conservation Organization
World Association of Soil and Water Conservation, China
International Union of Soil Science, Austria
European Society for Soil Conservation, Italy

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Editors

S. Manivannan
TBS Rajput
RAS Patel,
V. Kasthuri Thilagam
Nandlal Kushwaha
Mukesh Kumar
Manjushree Singh

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सत्यमेव जयते

प्रधान मंत्री
Prime Minister

MESSAGE

It is heartening to learn about the international conference on 'Sustainable Natural Resource Management under Global Climate Change' organised at New Delhi. The initiative undertaken by Soil Conservation Society of India (SCSI), in association with many national and international organisations is commendable.

Indian society has always had a harmonious relationship with nature. Sustainable development practices hold the key to ensure a combination of utilisation and preservation.

Soil conservation is a shared responsibility that affects our environment, well-being and future. Preserving soil health ensures a sustainable and prosperous future for the nation and its people.

Traditional Indian soil conservation practices including crop rotation through shifting cultivation, contour farming, bunding, and reduced tillage go a long way in promoting good soil health and reducing soil erosion. Through tireless efforts to provide Soil Health Cards, micro-irrigation and Atal Bhujal Yojana, soil health has shown a significant improvement in different parts of the country.

Along with soil conservation, prevention of soil degradation by reclaiming barren land helps ensure soil fertility and productivity.

The implementation of strategies like 'Per Drop More Crop' helps optimize water usage, while maximizing crop yields. Similarly, water conservation techniques, such as rainwater harvesting through time-tested practices such as 'Catch the rain' campaign and construction of stepwells underline India's deep-rooted wisdom in sustainable land and water management.

The building of a natural farming corridor along Maa Ganga is yet another effort to promote natural farming practices, as well as boost soil and water health.

The period till 2047 is an opportunity to realise the vision of building a glorious, self-reliant and sustainable nation. The building of Amrit Sarovars in every district is one such endeavour aimed at enhancing water availability, as well as retaining soil moisture.

The gathering of national and global experts in soil health and water conservation at this conference will help prepare a futuristic blueprint for the benefit of farmers and the agricultural community.

Best wishes for successful deliberations at the conference.

(Narendra Modi)

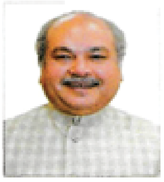
New Delhi
कार्तिक 12, शक संवत् 1945
03rd November, 2023

नरेन्द्र सिंह तोमर
NARENDRA SINGH TOMAR

D.O. No. 1071 /AM

सत्यमेव जयते

कृषि एवं किसान कल्याण मंत्री
भारत सरकार
कृषि भवन, नई दिल्ली
MINISTER OF AGRICULTURE & FARMERS WELFARE
GOVERNMENT OF INDIA
KRISHI BHAWAN, NEW DELHI



MESSAGE

I congratulate Soil Conservation Society of India for their efforts to jointly organize International Conference on **Sustainable Natural Resource Management under Global Climate Change** with Indian Agricultural Research Institute, International Soil Conservation Organization, International Union of Soil Sciences, and World Association of Soil and Water Conservation and supported by Indian Council of Agricultural Research (ICAR), Ministry of Agriculture and Farmers Welfare, Ministry of Jal Shakti and other international organizations.

My best wishes to make this event a grand success.

(Narendra Singh Tomar)

Office : Room No. 120, Krishi Bhawan, New Delhi-110 001 Tel.: 23383370, 23782691 Fax : 23384129
Resi. : 3, Krishna Menon Marg, New Delhi-110001, Ph. : 011-23794697 / 98, Fax : 011-23794696

गजेन्द्र सिंह शेखावत
Gajendra Singh Shekhawat

सत्यमेव जयते

जल शक्ति मंत्री
भारत सरकार
Minister for Jal Shakti
Government of India

1 8 SEP 2023

MESSAGE

There is no doubt that modern agriculture has delivered increases in food production that were unimaginable only a half a century ago. But many parts of the world, these gains have resulted in enormous consequences for the natural resource base and ecosystems that we all depend on. Groundwater reserves in many parts of Asia, and particularly parts of India, are running out; soils have become seriously degraded; rivers have become polluted and in some cases have completely run dry. With the world population expected to reach 9 billion by 2050, these problems are likely to become increasingly severe.

I am very pleased to support the efforts of the Soil Conservation Society of India in jointly organizing the 5th International Conference on **Sustainable Natural Resource Management under Global Climate Change** during November 7-10, 2023 at New Delhi and the Indian Council of Agricultural Research (ICAR) as a sponsor.

I hope that the deliberations and discussions during the conference will culminate in meaningful strategies for the sustainable use our precious natural resources to alleviate hunger, improve the quality of life, and safeguard the environment.

I wish you a successful and productive meeting.

(GAJENDRA SINGH SHEKHAWAT)

जल शक्ति अभियान
संचय जल, बेहतर कल

Office : 210, Shram Shakti Bhawan, Rafi Marg, New Delhi-110 001
Tel: No. (011) 23711780, 23714663, 23714200, Fax : (011) 23710804
E-mail : minister-jalshakti@gov.in

कैलाश चौधरी
KAILASH CHOUDHARY

सत्यमेव जयते

कृषि एवं किसान कल्याण
राज्यमंत्री
भारत सरकार
MINISTER OF STATE FOR AGRICULTURE
& FARMERS WELFARE
GOVERNMENT OF INDIA

MESSAGE

The agriculture and allied sectors continue to be the largest source of livelihood security for millions of households across the world. The demand for food, feed, fiber and fuel is on rise that has led to intensification in agriculture. Also, there is increased exploitation of natural resources such as land and water for non-agricultural use due to rising global population, urbanization and industrialization.

In the Indian context, the Conference would provide solutions in achieving our goal of sustaining agricultural growth and sustaining natural resources. I am happy to note that the theme of the Conference that cover overall agricultural development. I hope that the deliberations of the Conference will result in a road map in support of holistic development and come out with recommendations for future strategies and innovation for applications in the entire value chain with farmers and market occupying the central place.

I congratulate Soil Conservation Society of India for organizing International Conference on **Sustainable Natural Resource Management under Global Climate Change** in collaboration with Indian Agricultural Research Institute, International Soil Conservation Organization, International Union of Soil Sciences, and World Association of Soil and Water Conservation supported by Indian Council of Agricultural Research (ICAR), Ministry of Agriculture and Farmers Welfare and other international organizations.

(Kailash Choudhary)

अजय तिर्की, भा.प्र.से.
सचिव
Ajay Tirkey, I.A.S.
Secretary

सत्यमेव जयते

आज़ादी का अमृत महोत्सव

भारत सरकार
भूमि संसाधन विभाग
ग्रामीण विकास मंत्रालय
Government of India
Department of Land Resources
Ministry of Rural Development

MESSAGE

Sustainable Natural Resource Management (SNRM) is essential for addressing the challenges of global climate change. Natural resources, such as land, water, forests, and biodiversity, are already under pressure from anthropogenic activities, and climate change is exacerbating these pressures. SNRM can help to build resilience to climate change and reduce greenhouse gas emissions as well as generate green credits. Addressing the matter of SNRM in rural areas is a must to promote sustainable agriculture development & creating a more sustainable food production system to feed the growing population as well as optimize usage of natural resources.

I commend the Soil Conservation Society of India for organizing International Conference on ***"Sustainable Natural Resource Management under Global Climate Change"*** during 07-10 November, 2023 at NAAS Complex, New Delhi jointly with Indian Agricultural Research Institute, International Soil Conservation Organization, International Union of Soil Sciences, and World Association of Soil and Water Conservation and supported by Indian Council of Agricultural Research (ICAR), Ministry of Agriculture and Farmers Welfare, Department of Land Resources, Ministry of Rural Development, Ministry of Jal Shakti and other international organizations.

I am happy to note that the themes of the International Conference cover the most pertinent issues in the context of SNRM, overall sustainable agricultural development and conservation of natural resources in changing climate scenario. I hope that the deliberations of the Conference will be fruitful and will bring out useful recommendations, especially for the development of small and marginal farmers of the country.

I convey my best wishes for the success of International Conference!

(Ajay Tirkey)

सत्यमेव जयते

डॉ. हिमांशु पाठक
DR. HIMANSHU PATHAK
सचिव (डेयर) एवं महानिदेशक (आईसीएआर)
Secretary (DARE) &
Director General (ICAR)

भारत सरकार
कृषि अनुसंधान और शिक्षा विभाग एवं
भारतीय कृषि अनुसंधान परिषद
कृषि एवं किसान कल्याण मंत्रालय, कृषि भवन, नई दिल्ली–110 001

GOVERNMENT OF INDIA
DEPARTMENT OF AGRICULTURAL RESEARCH AND EDUCATION (DARE)
AND
INDIAN COUNCIL OF AGRICULTURAL RESEARCH (ICAR)
MINISTRY OF AGRICULTURE AND FARMERS WELFARE
Krishi Bhavan, New Delhi 110 001
Tel: 23382629 / 23386711 Fax: 91-11-23384773
E-mail: dg.icar@nic.in

Message

I am happy to know that International Conference on **Sustainable Natural Resource Management under Global Climate Change** is being organized jointly by the Soil Conservation Society of India, International Soil Conservation Organization, International Union of Soil Sciences, World Association of Soil and Water Conservation during November 7-10, 2023 in New Delhi, India.

Natural resources are critically important components of life support system. The conservation and management of natural resources are vital to achieve food and livelihood security. The technologies of natural resource conservation play major role for mitigating the impact of climate change on yield of various crops. The degradation of our natural resources, soil and water has become a matter of serious concern for the farmers, researchers, academicians, scientists and policy makers, and need to discuss with respect to food security and livelihood. I believe that the deliberations during the Conference will culminate in developing strategies and an action-oriented roadmap to promote conservation of natural resources and actions for combating the adverse effect of climate change.

I wish the the International Conference a grand success.

(Himanshu Pathak)

14th September, 2023
New Delhi

MESSAGE

I am pleased to learn that the Soil Conservation Society of India is jointly organizing an International Conference on **Sustainable Natural Resource Management under Global Climate Change** with Indian Agricultural Research Institute, International Soil Conservation Organization, International Union of Soil Sciences, and World Association of Soil and Water Conservation and supported by Indian Council of Agricultural Research (ICAR), Ministry of Agriculture and Farmers Welfare, Ministry of Jal Shakti and other international organizations.

The agriculture is now facing a big challenge to enhance food and nutritional security to meet the demand of ever-increasing human population of the world. This is due to degradation and depletion of natural resources. The on-going effects of climate change are further complicating the situation.

I am sure that the deliberations in the conference would provide solutions in achieving our goal of sustainable natural resource management under global climate change.

My best wishes for the success of the Conference.

(FAIZ AHMED KIDWAI)
CEO, NRAA

Dr. NEELAM PATEL
SENIOR ADVISER
Tel : 011-23096613
E-mail : neelam.patel@gov.in

सत्यमेव जयते

भारत सरकार
नीति आयोग, संसद मार्ग,
नई दिल्ली-110 001
Government of India
NATIONAL INSTITUTION FOR TRANSFORMING INDIA
NITI Aayog, Parliament Street,
New Delhi-110 001

October 27, 2023

MESSAGE

I am delighted to know that the Soil Conservation Society of India will be hosting the International Conference on "**Sustainable Natural Resource Management under Global Climate Change**" from November 7 to 10, 2023, in New Delhi in collaboration with Indian Agricultural Research Institute (IARI), International Soil Conservation Organization (ISCO), International Union of Soil Sciences (IUSS) and World Association of Soil and Water Conservation (WACWAC).

Modern agriculture has significantly boosted food production, yet it has strained natural resources. Depleting groundwater reserves in Asia, especially India, soil degradation, and polluted or dried-up rivers pose major challenges. With a projected global population of 9 billion by 2050, these issues are set to worsen. Effective soil and water management, given the changing climate, is crucial for sustainable agriculture, impacting society, economy, environment, and politics. Efficient conservation and management of natural resources are vital for food security, economic growth, and rural development. The degradation of natural resources is posing challenge to various stakeholders, including farmers, researchers, academicians, scientists, and policymakers, impacting rural development, food security, and livelihoods.

I have every confidence that this International Conference will offer a distinctive platform for delegates to discuss various strategies in natural resource management, addressing the challenges of climate change in tandem with rural development to bolster food and livelihood security. I am optimistic that the conference will achieve remarkable success. These deliberations will, I believe, result in the formulation of effective strategies and an actionable roadmap for promoting natural resource conservation and combating the adverse effects of climate change. My best wishes are extended for the success of this significant event.

(Dr. Neelam Patel)

स्वच्छ भारत
एक कदम स्वच्छता की ओर

भा.कृ.अ.प. – भारतीय कृषि अनुसंधान संस्थान, नई दिल्ली–110012 (भारत)
ICAR - INDIAN AGRICULTURAL RESEARCH INSTITUTE
(A DEEMED TO BE UNIVERSITY UNDER SECTION 3 OF UGC ACT, 1956)
NEW DELHI - 110012 (INDIA)

डॉ. अशोक कुमार सिंह, एफ.एन.ए., एफ.एन.ए.एस.सी., एफ.एन.ए.ए.एस.
निदेशक एवं कुलपति
Dr. Ashok Kumar Singh, FNA, FNASc, FNAAS
Director & Vice Chancellor

Phones : 011-2584 2367, 2584 3375
Fax : 011-2584 6420
E-mail : director@iari.res.in
Personal : aks_gene@yahoo.com
Website : www.iari.res.in

Message

Sustainable management of natural resources is vital for achieving many sustainable development goals (SDGs) at regional, national and global scale. The mounting anthropogenic pressure on natural resources along with driving force of climate change leading to irreversible degradation of soil, water, vegetation and biodiversity. The concern is already being voiced by researchers, planners and farmers. The state of natural resources impacting our agro-eco systems, therefore, needs constant monitoring to devise safe and appropriate resources use strategies.

I am pleased to know that Soil Conservation Society of India (SCSI) New Delhi is going to organize 5th International Conference on "Sustainable Natural Recourses Management under Global Climate Change at New Delhi from 7-10 November, 2023. I believe that the deliberation of this convention will provide an interactive platform to come out with some useful recommendation in saving our natural resources for posterity and achieving many SDG Targets.

I wish this International Conference a grand success.

AKSingh

(A.K. SINGH)

National Academy of Agricultural Sciences

Dr. Anil K. Singh
Vice President

Dated: September 19, 2023

MESSAGE

The two natural resources, namely, soil and water has played a crucial role in enhancing the agricultural productivity and alleviating hunger and poverty on the globe. However, intensive agricultural related activities coupled with injudicious and uncontrolled use of these resources has led to their degradation. Global warming is going to adversely affect soil health and modify the hydrological behavior of the water cycle impacting productivity. The recent changes in rainfall pattern, intensity and enhanced uncertainty are evidences of these impacts. The soil and water conservation technologies play a major role in mitigating climate change impact on yield of various crops. In the past, the choice of technologies and their adoption was to reduce soil erosion, rehabilitate degraded lands and enhance soil moisture retention resulting in enhancement in yield. The soil and water conservation technologies now need to be made more socially acceptable, environment and climate smart to minimize the adverse impact on soil and water resources under different ago eco systems. Therefore, developing an interface among academicians, researchers, government departments, policy makers, farmers, industry and other stake holders will be vital for preparing a road map for developing such technologies.

In this context, International Conference on Sustainable Natural Resource Management under Global Climate Change which is being organized from 7-10 November, 2023 at New Delhi, India, led by the Soil Conservation Society of India jointly with International Soil Conservation Organization, International Union of Soil Sciences, World Association of Soil and Water Conservation, National Academy of Agricultural Sciences (NAAS) and sponsored by Indian Council of Agricultural Research (ICAR) is timely and praiseworthy.

It is hoped that the deliberations and discussions during the Conference will come out with concrete recommendations that will be useful in developing strategies, demand-driven research programmes and an action oriented road map for conservation and management of natural resources, enhancing food production and identify options for mitigating the adverse effect of climate change.

I extend my warm wishes for the success of the International Conference.

(Anil K. Singh)

NASC, Dev Prakash Sastry Marg, P.O. Pusa, New Delhi-110 012
Tel.: 91-11-25846051-52, Fax: 91-11-25846054; Email: naas-mail@naas.org.in; Web site: http://www.naasindia.org

NING Duihu

MESSAGE

It is a matter of pleasure that Soil Conservation Society of India is organizing an International Conference on "Sustainable Natural Resource Management under Global Climate Change" at New Delhi during 07-10 November, 2023.

Land, water, soil and vegetation are the most important natural resources which need to be managed scientifically for sustainable development and to mitigate on site and off site effects on natural system. Climate change is one of today's most emerging global issues and will become increasingly important in the decades to come, a matter of concern. Its impacts are cross cutting in all sectors and walks of life; however, agriculture sector is among the most vulnerable sectors to the impacts of climate change. During last few decades, over exploitation and irrational use of natural resources has led to degradation and changes in the climate.

I believe that the experts, scientists, academicians, researchers and students participating in the Conference will deliberate on various issues, discuss various options, experiences and come out with some recommendations for sustainable management of natural resources and climate resilience.

President of the World Association of Soil and Water Conservation

SOIL CONSERVATION SOCIETY OF INDIA

Dr. TBS Rajput
President, SCSI

MESSAGE

The agriculture and allied sectors continue to be the largest source of livelihood security for millions of households across the world, especially in the developing countries. The escalating demand for food, feed, fiber and fuel has led to intensification of agriculture. Further, there is increased diversion of natural resources such as land and water for non-agricultural use due to rising global population, urbanization and industrialization. The soil health and water quality are reducing with time. The farmer has to produce more from minimum available resources. This necessitates innovations for improving efficiency, equity and environment with simultaneous enhancements in farm productivity and profitability under changing climate scenario.

In this endeavor, joint efforts of the Soil Conservation Society of India, Indian Agricultural Research Institute, International Soil Conservation Organization, and World Association of Soil and Water Conservation are organizing the International Conference on **Sustainable Natural Resource Management underGlobal Climate Change**, is timely and praiseworthy.

It is my trust and belief that the Conference will bring the finest brains of the world together to chalk out strategies for sustainable growth of agriculture without stressing soil, water, energy and biodiversity resources on the one hand and boosting health of environment on the other.

I send my warm wishes for the success of the International Conference.

(TBS Rajput)

Registered Office: National Societies Block, G-4/A, National Agricultural Science Centre (NASC) Complex, Dev Prakash Shastri Marg, Pusa, New Delhi-110012, INDIA Ph.: +91-11-25848244; Mobile: +91-9868808980
Email:soilcsi@gmail.com; bhan_suraj1945@yahoo.com
Website: www. scsi.org.in

S.Manivannan

Organizing Secretary

Exordium

Water, soil, forests, wildlife and fisheries are the important natural resources for the billions of people around the globe. Worldwide gradual shifting in weather patterns, rising sea levels, and frequent extreme events are all clear evidence of a rapidly changing climate. It threatens human life, global ecosystems, and our efforts to sustainable development.Climate change directly and indirectly affects agricultural productivity and natural resources.The changing climate pattern urges sustainable natural resource management, that often bolsters resilience. Natural resource management for climate change mitigation and resilience is the need of the hour.

Keeping this in view, the Soil Conservation Society of India New Delhi is organizing the 5th International Conferenceon Sustainable Natural Resource Management under Global Climate Change" at the National Agricultural Science Centre (NASC), New Delhi, Indiaduring November 7-10, 2023. The International conference is organized in collaboration with ICAR - Indian Agricultural Research Institute, New Delhi, National Academy of Agricultural Sciences (NAAS), India, International Soil Conservation Organization, India,World Association for Soil and Water Conservation, China, International Union of Soil Science, Austria and European Society for Soil Conservation. TheInternational Conference is intended to discuss the emerging new issues on sustainable management of natural resources and come up with a list of fruitful recommendationsto mitigate the impact of climate change. This conference would provide an opportunity for various stakeholders to share their experiences, knowledge, findings and success stories.This souvenir has articles of assorted ideas and research findings of eminent scientists working in the field of climate change and natural resource management.

I express my sincere gratitude to Dr. Himanshu Pathak, Secretary (DARE) and Director General (ICAR) for his encouragement and guidance for organizing this conference. My heartfelt thanks are due to Dr Tilak Raj Sharma, DDG (Crop Science), for his constant support and motivation. Heartfelt thanks are due to Dr. Ashok Kumar Singh, Director & Vice Chancellor, ICAR – IARI, New Delhi, for his guidance and constant support in conducting this conference. Sincere thanks are due to Dr. Anil Kumar, ADG (Coordination) for his valuable support for organizing this conference. I am thankful to Late Dr. Suraj Bhan, former President, SCSI and Dr TBS Rajput, President SCSI, for guiding me in organizing the event and bringing out this publication.

I gratefully acknowledge the financial support extended by the Indian Council of Agricultural Research, India, Ministry of Jal Sakthi, Government of India, Department of Land Resources, Government of India, National Jute Board, Kolkata, National Rainfed Area Authority (NRAA), Indian Oil Corporation Ltd., National Biodiversity Authority and Gas Authority of India Ltd. Conference facilities provided by National Academy of Agricultural Sciences (NAAS) is highly acknowledged. I also express my sincere thanks to all the co-sponsorers and advertisers for their financial support. I sincerely thank all authors who contributed their valuable findings to this publication.

Dr. S. Manivannan
Organizing Secretary

Date: 07.11.2023

New Delhi

Contents

CLIMATE CHANGE IMPACT ON INDIAN AGRICULTURE

Himanshu Pathak

Secretary, Department of Agricultural Research and Education & Director General,
Indian Council of Agricultural Research
New Delhi

The agriculture sector's role in greenhouse gas (GHG) emissions is widely known but poorly understood. It has been reported that more than one-quarter of the world's GHG emissions come from agriculture, forestry, and land-use change. Global greenhouse gas emissions have continued to increase, with unequal historical and ongoing contributions arising from unsustainable energy use, land use and land-use change, and changes in lifestyles and patterns of food consumption and production across regions, between and within countries, and among individuals. Human activities, principally through emissions of greenhouse gases, and a naturally occurring El Niño event have unequivocally caused global warming. Global near-surface temperature are likely to surge to a record levels in the next five years, each year between 2023 and 2027 is predicted to be between 1.1°C and 1.8°C; higher than the 1850-1900 average, according to a new update issued by the World Meteorological Organization (WMO) (Anonymous, 2023).Global Warming of 1.5°C, the 2018 report by the Intergovernmental Panel on Climate Change (IPCC), makes clear that a "rapid and far-reaching" transition is required to limit the impact of climate change to 1.5 degrees Celsius.

During recent years, substantial evidence of climate change has been observed across the globe. Conversely, better ways of characterizing and quantifying uncertainty have underscored the challenges that remain unnoticed for developing long-term global and regional climate quality data records (Alexander *et al*., 2006). It has been reported that globally averaged combined land and ocean surface temperature data estimated by linear trend that there has been a warming of 0.85 [0.65 to 1.06] °C, over 1880–2012 (Liu *et al.* 2020). It was also observed that the total increase in temperature between the average of the 1850–1900 period and the 2003– 2012 period is 0.78 [0.72 to 0.85] °C (Sa'adin *et al*., 2016) and the total increase between the average of the 1850–1900 period and the reference period for projection 1986-2005 is 0.61 [0.55 to 0.67] °C (Ozturk *et al*., 2020). It is distinctly possible that on a global level, cold days and nights have decreased and warm days and nights have increased since 1950 (Brown *et al*., 2008). It is also noted that extreme rainfall events in the country are on the rise (Guhathakurta *et al*., 2011). There is a 98% likelihood that at least one of the next five years, and the five-year period as a whole, will be the warmest on record. As per WMO we need to be prepared for far-reaching consequences for health, food security, water management and the environment as a warming El Niño is expected to develop in the coming months and will combine with human-induced climate change to push global temperatures into uncharted territory. It is also very likely that heat wave frequency has increased during this period in large parts of Asia, Australia and Europe. India's average temperature rose by around 0.7°C from 1901 to 2018. This temperature rise is mainly due to GHG-induced warming, partially offset by forcing due to anthropogenic aerosols and changes in LULC. The impact of climate change in India is discussed below.

Temperature Rise

In the Indian context, it was revealed that the mean annual surface air temperature has increased by 0.4-0.6°C in the last 100 years (Kothawale and Rupakumar 2002). The average duration of heat wave events is also projected to approximately double, but with a substantial spread among models (Krishnan *et al*., 2020). In response to the combined rise in surface temperature and humidity, amplification of heat stress is expected across India, particularly over the Indo-Gangetic and Indus river basins (Sanjay *et al.,* 2021).

Changes in Rainfall

Warming due to increasing concentration of atmospheric GHGs and moisture content is generally expected to strengthen the Indian monsoon. Few studies also reported the decreasing rainfall tendency in both southwest and northeast monsoon seasons in most parts of central and northern India since 1950 (Annamalai 2010, Kulkarni 2012), with particularly notable decreases in parts of the Indo-Gangetic plains and the Western Ghats (Krishnan *et al*., 2013; Roxy *et al*., 2015). Climate modelling studies suggest that the observed changes have resulted in response to the radiative effects of the northern hemispheric (NH) anthropogenic aerosols and regional LULC, which have more than offset the precipitation enhancing tendency of GHG warming in the past 6 to 7 decades (e.g. Bollasina *et al*., 2011; Krishnan *et al.* 2016; Sanap *et al*., 2015; Undorf *et al*., 2018).

In contrast, localized heavy precipitation occurrences have risen significantly over Central India in the past 6 to 7 decades (Roxy *et al*., 2017; Mukherjee *et al*., 2018). The peninsular parts of India, particularly over the region from 9-16^0 N encompassing the rice growing areas showed an increasing rainfall tendency. This increase was particularly strong during the northeast monsoon season. With anticipated reductions in NH aerosol emissions, future changes in the monsoon precipitation are expected to be prominently constrained by the effects of GHG warming. With the resultant increase in temperature and atmospheric moisture, climate models project a considerable rise in the mean, extremes and inter-annual variability of monsoon precipitation by the end of the century (Kitoh 2017). The summer monsoon precipitation (June to September) has declined by around 6% from 1951 to 2015, with notable decreases over the Indo-Gangetic Plains and the Western Ghats. There is an emerging consensus, based on multiple datasets and climate model simulations, that the radiative effects of anthropogenic aerosol forcing over the Northern Hemisphere have considerably offset the expected precipitation increase from GHG warming and decline in summer monsoon precipitation (Krishnan *et al.,* 2020).

There has been a shift in the recent period toward more frequent dry spells (27% higher during 1981–2011 relative to 1951–1980) and more intense wet spells during the summer monsoon season. The frequency of localized heavy precipitation occurrences has increased worldwide due to increased atmospheric moisture content. Over central India, the frequency of daily precipitation extremes with rainfall intensities exceeding 150 mm per day increased by about 75% during 1950–2015 (Krishnan *et al.,* 2020).

Since the middle of the twentieth century, India has witnessed a rise in average temperature, a decrease in monsoon precipitation, a rise in extreme temperature and rainfall events, droughts, and sea levels, and an increase in the intensity of severe cyclones, alongside other changes in the monsoon system. There is compelling scientific evidence that human activities have influenced these changes in regional climate. Human-induced climate change is expected to continue apace during the twenty-first century (Krishnan *et al*., 2020).

Droughts

The decrease in seasonal summer monsoon rainfall during the last 6–7 decades has led to an increased propensity for droughts in India. Both the frequency and spatial extent of droughts have increased significantly from 1951 to 2016. In particular, areas over central India, southwest coast, southern peninsula and north-eastern India have experienced more than two droughts per decade, on average, during this period. The area affected by drought has also increased by 1.3% per decade over the same period (Krishnan *et al*., 2020).

Indian agriculture

Indian agriculture is highly susceptible to the risks arising from climate change; especially drought. This is due to reason that 2/3rd of the agricultural land in India is rainfed and even the irrigated system is dependent on monsoon rainfall (Sharma *et al*., 2011). In many parts of the country, flood is the major problem where frequent flood events are taking place. In addition, frost in north-west, heat waves in central and northern parts and cyclone in eastern coast also cause major destruction. Recently, the frequency of these climatic extremes is increasing due to the increased atmospheric temperature (Kothawale *et al*., 2010). All these events have increased the risk of substantial loss of agricultural production. There are various direct and indirect effects of climate change on agriculture which affects the crops, soils, livestock and pests. An increase in atmospheric carbon dioxide has a fertilization effect on crops with C3 photo synthetic pathway and thus promoting their growth and productivity (Lemonnier *et al.,* 2018).

Increasing temperature may cause reduction in crop duration, increase in crop respiration rates, and alteration in photosynthesis. It can also affect the survival and distribution of pest populations which may give rise to a new equilibrium between crops and pests (Dusenge *et. al.* 2019). Increasing temperature also hastens nutrient mineralization in soils, decrease fertilizer use efficiencies, and increase evapo-transpiration (Brouder *et al.* 2008). Climate change also has a considerable indirect effect on agricultural land use in India due to the availability of irrigation water, frequency and intensity of inter- and intra-seasonal droughts and floods, soil organic matter transformations, soil erosion, changes in pest profiles, decline in arable areas due to submergence of coastal land, and availability of energy (Pathak *et al.* 2014). In the purview of climate change, some of the major challenges the agriculture sector would face are as follows:

- Agricultural water availability ; as result of changing rainfall patterns, alteration in stream flow and increase in crop water demand
- Deterioration of water quality; due to seawater intrusion, transport of salts from the deeper soil layers as a result of over-exploitation of aquifers and faulty irrigation practices.
- Increased frequency and intensity of extreme weather events such as droughts, floods and cyclones would affect production levels from agriculture
- Heat stress at critical growth stages of the crop.
- Unpredictable change in pest and disease load. There is also a possibility of minor pests becoming major pests with changing climatic conditions.

Adaptive measures for Indian agriculture in the scenario of climate change

There are various potential adaptation strategies to deal with the impact of climate change, such as developing the cultivars to heat and salinity stresses and resistant to flood and drought, modification in crop management practices, improving water management, adopting new farm techniques such as resource conserving technologies (RCTs), crop diversification, improving pest management, better weather forecasts and crop insurance and harnessing the indigenous technical knowledge of farmers (Negi and Rana, 2016). The key to maintaining yield stability in a changing climate is to develop new crop varieties with higher yield potential and resistance to multiple stresses (drought, flood, salinity). Breeding programmes shall focus on improving the germplasm of important crops for heat tolerance (Jha *et al*., 2014). Similarly, it is essential to develop tolerance to multiple abiotic stresses as they occur in nature. Enhancing the root efficiency to uptake water and nutrients from soil is also essential. Genetic engineering shall play a pivotal role for gene pyramiding, which pool all desirable traits in a plant to get the 'ideal plant type' which may also be 'adverse climate tolerant' genotype (Kaliya and Yadav 2015). Efficient use of natural resources such as water is critical for climate change adaptation. Therefore, With hotter temperatures and changing precipitation patterns, water will become a scarce resource (Trenberth, 2011). Prompt actions towards water conservation, water harvesting, and improvement of irrigation accessibility and water use efficiency will be essential for crop production and livelihood management. On-farm water conservation techniques, micro-irrigation systems for better water use efficiency and selecting appropriate crop-based irrigation have to be promoted (Kumar *et al*. 2008). There has been ever increasing need for technologies and investments that improve water management efficiency. In rainfed areas, water conservation and harvesting techniques are the only possible alternatives for poor farmers (Oweis and Hachum, 2006). Advance irrigation methods like drip irrigation, sprinkler irrigation and laser-aided land leveling can also help increase water-use efficiency. Laser aided leveling provides smooth and leveled field, allowing ideal water distribution with negligible water losses. It facilitates uniformity in the placement of seed/seedlings and fertilizer, which helps good plant stand, enhances nutrient use efficiency, and increases yield (Pathak *et al.,* 2012). Various water conservation structures like gully plugs, contour bunds, gabion structures, percolation tanks, check dams, recharge shafts and dugwell recharge structures can benefit rural water conservation (Jain, 2012).

Changes in planting dates to minimize the effect of high temperature-induced spikelet sterility can be used to reduce yield instability so that the flowering period does not coincide with the hottest period (Satishraj *et al*., 2016). Change in cropping systems like growing of suitable cultivar, crop diversification, crop intensification, etc. can be adopted (Altieri *et al*. 2015). Steps like developing cultivars which are resistant to the pests, integrated pest management with more emphasis on biological control and changes in cultural practices, pest forecasting using recent tools such as simulation modelling, alternative production techniques and identification of crops, as well as locations, that are resistant to infestations and other risks are very crucial in disease and pest management in changing climate situations (Baker *et al*. 2020).

Policy decisions like crop insurance schemes (private and public) should be put in place to help farmers reduce the risk of crop failure due to extreme climatic events. Micro-finance has been a success among rural poor, including women. Low-cost access to financial services could be a boon for vulnerable farmers (Dallimore, 2013). A growing mobile telephony network could further speed up SMS-based banking services and help farmers better integrate with financial institutions. A sustainable insurance system is needed, and the rural poor are to be educated about availing such opportunities.

Conservation agriculture and resource conservation technologies (RCTs) have proved to be highly useful in enhancing resource or input-use efficiency and provide immediate, identifiable and demonstrable economic benefits such as reductions in production costs, savings in water, fuel and labour requirements and timely establishment of crops resulting in improved yield (Negi and Rana, 2016). Farmers who are aware of weather events can respond by planting more appropriate crops or varieties. Forecasting weather events will help farmers adopt suitable crop management options (Hansen, 2002). An integrated approach involving all possible sectors of agro-ecosystem is the only option to address the impact of climate change on agricultural production and ensure food security. Now is high time for all scientists, researchers, educators, policymakers, intellectuals, and all to join together and take steps towards possible solutions for the problems raised due to climate change for agriculture.

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LAND DEGRADATION NEUTRALITY – CHALLENGES AND OPPORTUNITIES

Anil Kumar Singh

National Academy of Agricultural Sciences
NAS Complex, New delhi-110012, India

Introduction

The International Union for the Conservation of Nature (IUCN) and the Government of Germany launched the Bonn Challenge in 2011 targeting restoration of 150 Mha of deforested and degraded land by 2020 and 350 Mha by 2030. India was the first Asian country to join this Challenge, and initially pledged restoring 21 Mha of degraded land by 2030. Degraded land is the land that has lost at least 10% of its natural productivity due to human-caused management processes – land use shifts, deforestation, transgressing carrying capacity, exclusive focus on man-made inputs ignoring the use of organic manures and microbial potential, excessive tillage, etc. From the point of developing policies to reduce emissions from deforestation and forest degradation (REDD+), degraded lands refer to areas with low carbon stocks (<35t/ha). Among the 17 UN SDGs targeted to be achieved by 2030, the SDG 15.3 has a primary focus on achieving a Land Degradation Neutral (LDN) World. The LDN is defined as "a state whereby the amount and quality of land resources necessary to support ecosystem functions and services, and to enhance food security remain stable or increase within specified temporal and spatial scales and ecosystems" (UNCCD). It impacts several other 'SDGs' also (Fig. 1). Of the 196 countries, which participated in the 14th Conference of Parties (COP 14) of the United Nations Convention to Combat Desertification (UNCCD) in 2019, 123 countries, including India, had already committed targets on LDN. In this meeting, India increased its target from 21 to 26 Mha by 2030. It means restoring lost land productivity and ecosystem services of these degraded lands by adopting a 'landscape restoration approach'. The National Academy of Agricultural Sciences (NAAS) subsequently came up with an action plan for its implementation (NAAS, 2022).

Socio-economic and Environmental Costs

Globally, land degradation is affecting the well-being of at least 3.2 billion people, costing >10% of the annual global gross product. On an average, the benefits of land restoration are 10 times higher than the costs, estimated across nine different biomes (IPBES, 2018). It is predicted that by 2050, land degradation and climate change are likely to reduce crop yields by 10%, which may go up to 50% in some vulnerable regions. Land degradation will also force millions to migrate to safer havens by 2050. Annual economic loss due to land degradation and changes in land use has been estimated at Rs 3.17 lakh crore (US $46.90 billion) in 2014-15, equivalent to 2.5% of the gross domestic product (GDP) as per Business Standard Report (2018).

Impact of Restoration of Degraded Lands on Food Security

By 2050, India's population is likely to touch 1.68 billion. This implies that the carrying capacity of the land has to be restored with appropriate technological interventions. It is, therefore, imperative for India is to increase the productivity sustainably by infusion of holistic land management practices with a three-pronged approach, that is, to conserve the health and quality of existing land, restore lands lost to degradation, and sustain the quality of lands already restored. The interventions must be farmer-centric and focus on improving the bio-physical resources of production systems. Holistic land management implies harmonization of efficient use of inputs and native resources including mainstreaming the role of livestock and biologically enhanced soil technology. A strong policy supporting R&D would be essential to fulfil the country's commitment of LDN.

Monitoring Indicators

The United Nations Convention to Combat Desertification COP 11 (Convention of Parties) (UNCCD, 2013) *(https://www.unccd.int/sites/default/files/sessions/documents/ICCD_COP12 _4/4eng.pdf)* suggested three indicators for reviewing LDN projects i.e. changes in land cover, land productivity (or net primary productivity) and carbon stocks [or soil organic carbon (SOC)] measured up to a depth of 30 cm. A positive outcome of all the three indicators is must to certify that the goal of any LDN project has been achieved; with one-out-all-out principle. It is said that a positive impact will serve the cause of sustaining economic productivity and provisioning environmental services – the two drivers describing sustenance of soil health and land quality. Of the three criteria, yield shifts are faster in response to regenerative treatment or bad management while SOC changes are comparatively slower. Though under natural conditions, the land cover changes are slow, sudden land use changes like diversion of green covers for infrastructure can have an immediate impact. Logging is another example of damage to vegetative shield that protects the land from degradation. Cowie et al. (2018) added an additional

Fig. 1: Impact of SDG 15.3 on other SDGs

parameter i.e. a scientific approach to public policy, which reflects government's willingness to implement and enforce a mechanism for monitoring LDN progress. They also suggested a set of socio-economic outcome indicators (right on land, tenancy laws, and payment for environmental services) to assess medium and long-term impact of LDN projects.

Strategies for Rehabilitation of Degraded Land

An objective analysis of the existing strategic action plans, covering various aspects and issues of LDN, was carried out by Katyal (2020). Application of holistic management of an agroecosystem needs focus while prescribing activities and practices to rejuvenate lands suffering from degradation. Accordingly, several innovative methods have been recommended to fulfill the commitment of rehabilitating degraded lands. Rehabilitation options vary across ecosystems and some ecosystems may need several technologies for rehabilitation of degraded land; however, the priority of implementation depends on the nature of technology and its cost. Soil erosion reduction with prolonged period of soil cover was considered as the most effective option for land restoration (Lal, 1990; Srinivasarao et al., 2013). Technologies currently available are summarized in Table 1.

The Way forward

- It is important to bring public institutions, civil society organizations (NGOs), and forest-dependent communities (FDCs) on a common platform for restoring lost soil cover (reforestation), and afforesting denuded and barren land. Public institutions may provide technology, quality planting material, and logistic support. FDCs should develop planting sites, ensure after care, and have specific rights to utilize products generated from the developed forest. The NGOs should facilitate collaborative activities.

Table 1: Land restoration technologies for various types of degradation

Sl. No.	Degradation type	Technology	States
1.	Water Erosion	Contour farming; contour bunding; bench terracing, contour trenches, half-moon terracing, strip cropping, mulching, conservation agriculture, agroforestry, mulch cum manuring, aerial grassing, cover crops, bund stabilization, rainwater conservation, and farm ponds, watershed management, silt traps in farm ponds, relay cropping, tank silt recycling, intercrops etc.	Arunachal Pradesh, Assam, Manipur, Meghalaya, Nagaland, Tripura, Delhi, Haryana, Himachal Pradesh, Jammu and Kashmir, Punjab, Uttar Pradesh, Uttarakhand, Bihar, Jharkhand, West Bengal, Chhattisgarh, Madhya Pradesh, Maharashtra, Andhra Pradesh, Karnataka, Kerala, Tamil Nadu.
2.	Wind Erosion	Planting of trees in borders of agricultural lands to act as shelterbelts; mulching, strip cropping, high density planting, agroforestry, sand dune stabilization, grassing, etc.	Rajasthan and adjoining areas.
3.	Salinity/ Alkalinity/ Sodicity	Tolerant tree species cultivation (Planting of Salvadoraoleoides, T. troupii, etc.) to reduce the EC levels; Gypsum application for high alkali soils; leaching process for reducing salinity; green manuring; growing tolerant crop species, on farm generation of organic matter and recycling.	Haryana, Punjab, Uttar Pradesh, Bihar, Gujarat, Rajasthan, Andhra Pradesh, Tamil Nadu.
4.	Soil Acidity	Lime application, growing acid tolerant varieties, plantation cropping, fruit cropping, agroforestry, organic matter addition, cultivation of legumes	Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, Tripura, Haryana, Himachal Pradesh, Jammu and Kashmir, Uttarakhand, Bihar, Jharkhand, West Bengal, Chhattisgarh, Maharashtra, Kerala, Tamil Nadu.
5.	Soil Fertility Depletion	Judicious use of chemical fertilizers; Combined application of fertilizers with organic amendments-INM; SSNM, Introduction of legumes in mono-cropping, mulching, green manuring, conservation agriculture, crop residue recycling, biochar and biofertilizers and legume cover crops, location specific Indigenous technical knowledge practices like sheep penning etc.	Andhra Pradesh, Telangana, Karnataka, Tamil Nadu, Maharashtra, Rajasthan, Gujarat and others.
6.	Soil Compaction	Subsoiling and organic matter addition	Vertisols of Maharashtra, North Karnataka, Madhya Pradesh.
7.	Water Logging	Adoption of integrated nutrient management, intercultural operations and water use efficient technologies, provision of drainage	Heavy rainfall and High clay soils, Maharashtra, Karnataka, AP, MP, Chhattisgarh, etc. Canal irrigated areas
8.	Barren/ Rocky Lands	Biofuel plantations; medicinal and aromatic plantation; agroforestry, afforestation, tank silt addition.	Arid areas in the country

- Productive lands should not be permitted to be diverted for other uses by enacting an effective legal instrument to minimise and eliminate encroachment of public and common (common property resources) lands.
- Introduce site-appropriate agriculture production systems as per Land Capability Classification (LCC).

GROUNDWATER DEPLETION – A THREAT TO RESILIENCE OF OUR FUTURE

R. C. Srivastava

Former Vice-Chancellor, RPCAU, Pusa, Bihar

Introduction

Groundwater in India is a critical resource for most of the major user sectors like agriculture, industry, and domestic. With the growth in pollution and industrialization, dependency on groundwater is increasing, resulting in unsustainable levels of overexploitation. If current trends continue, around 60 percent of India's aquifers will be in critical condition in 20 years, which will have severe implications for the sustainability of agriculture, long-term food security, livelihoods and economic growth in the country. Presently, total water availability is 4000 BCM (billion cubic meters), out of which green water is 2169 BCM and blue water is 1831 BCM. Out of blue water availability, the total water available for utilization is 1123 BCM with 691 BCM surface water and 432 BCM groundwater. About 60% of groundwater is exploited, but the future scenario is grim. A study has found that India will lose groundwater three times faster in 2041-2080, mainly due to global warming. As the country becomes warmer, people will draw more water from underground, leading to faster depletion, the researchers wrote in the paper published in Science Advances. Across climate change scenarios, the researchers found that their estimate of groundwater level (GWL) declines from 2041 to 2080 is 3.26 times current depletion rates on average (from 1.62-4.45 times) depending on the climate model and Representative Concentration Pathway (RCP) scenario (Zumbish, 2023).

Impact of Groundwater Depletion

Discussions about groundwater depletion are mainly concerned with reduction in water availability. However, very few know that India's depleting groundwater levels are changing the shape of the land above. Experts warn that as water disappears from aquifers, the land may suddenly or gradually sink, leading to a phenomenon known as land subsidence. Underground water exists deep in the earth's surface, occupying the void left by soil pores or rock cracks. At those depths, water is pressurized and it pushes the earth up. "The weight of the earth is shared by both the water and the matter underneath," said Shagun Garg, a civil engineer and researcher at the University of Cambridge. "When the groundwater is drawn out excessively, the matter underneath becomes the sole entity for managing the load" (Monica Mandal, 2022). Studies in the Delhi NCR region reported that the land has sunk and continues to sink at a substantial rate. Certain parts of Delhi, like Kapashera, near the Indira Gandhi International Airport, witnessed a land subsidence rate of 11 cm per year during 2014-2016, which grew to more than 17 cm per year during the two years that followed. Researchers have also studied the Gangetic region from Punjab to West Bengal and Gujarat and have found prevalent evidence of land sinking (nasa.gov/topics/earth/features/india_water.html; sciencedirect.com/science/article/abs/ pii/s0034425706000757; link.springer.com/article/10.1007/s10064-021-02111-x).

The sinking of the earth depends on many factors, including the fragility and type of earth. "If limestone presence in the ground is high, it can dissolve in the water," further leading to compaction, explains Garg as reported by Monica Mandal (2022). She reports that other reasons like excessive coal or petroleum mining can also play a role in some cases. But in cases where the earth matter is made up of thin soil particles, like the alluvial deposits of fertile Gangetic plains, land sinking becomes more prevalent compared with the hard rocks. By 2040, land subsidence will affect about 8% of the world's surface and about 1.2 billion inhabitants living in 21% of the major cities worldwide. Like many other disasters, land subsidence is predicted to impact Asia more than other parts of the world. With 86% of the Asian population exposed to the effects of land subsidence, about $8.17 trillion is potentially at stake.

This uneven subsidence is leading to increased incidences of road caving. Most of the time, the blame is laid on poor workmanship, but the culprit is our declining groundwater table. If the sinking of land is spread over a wide region, then it may mean that the area may become prone to flooding.

National Capital Region Delhi faces a severe water crisis due to increasing demand. This map analyses hazard risk and vulnerability, highlighting an approximate area of 100 sq km to be subjected to the highest risk level of ground movement, demanding urgent attention. However, in cases where the rate of sinking is differential, it may impact the civil infrastructure like roads, buildings, and houses. It might lead to the weakening of foundations (Fig. 2 and 3).

In hard rock aquifer areas, this land subsidence activates the shifting of tectonic plates, resulting in earthquakes. The earthquake of Latur (Maharashtra) in 1993 is one example where groundwater level had gone much below and was in the least sensitive zone (Fig. 4).

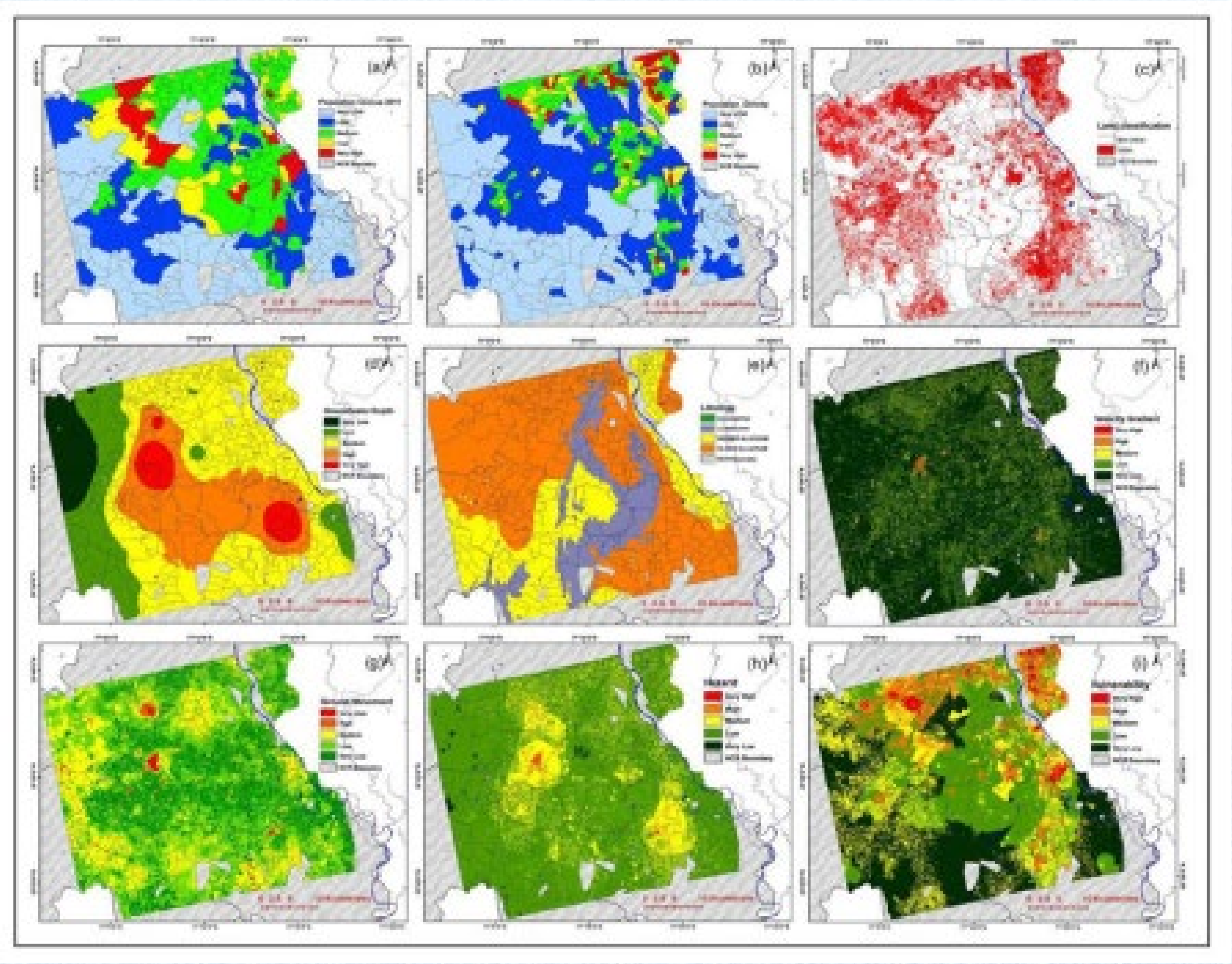

Fig. 1: Hazard risk and vulnerability in National Capital Region Delhi

Fig. 2: Caving of roads

Another aspect which is being ignored is fast reduction in dry seasonal flow of rivers. Mostly it is viewed as effect of dwindling forest cover and change in land use of river catchment areas. However, very few attempts have been made to correlate it with declining groundwater levels. Figure 5 shows how a fully recharged groundwater feeds river flow during lean season i.e., post monsoon. In normal conditions of groundwater level, it is recharged during monsoon and post monsoon it feeds river flow. However, if the groundwater level goes below the river bed level due to excessive withdrawal, this flow is restricted and lean season flow declines. The situation becomes even graver when excessive silt deposit in the river raises the river bed above the groundwater level.

Fig. 3: Damage to building due to sinking of land

Fig. 4: Devastation due to earthquake in Latur a least sensitive zone in 1993

Groundwater depletion also affects energy consumption. With depleting groundwater resources, depth of tubewells have started increasing to earlier unthinkable depths. Depths which were earlier 150- 200 feet went on to 500-600 feet. This increased energy costs for pumping water, and quality issues due to over-extraction. A farmers survey in 2014-15 to know timeline on changes in size of tubewells in Muzaffarnagar district of U.P. indicated that in pre 1995, farmers had 5 hp centrifugal pumps. Post 1995, they shifted to submersible pump as centrifugal pumps became defunct due to falling water tables. By 2000, they had to replace 5 hp pumps by 7.5 hp pumps. They had to change pumps again to 10 hp pumps by 2010 which became new normal. In some areas it had gone to 12.5 hp and even 15 hp in exceptional cases (Srivastava, 2014, Personal discussion). This scenario explains increased energy cost and, therefore cost of irrigation cost and finally cost of cultivation. Besides an environmental disaster in offing, more visible effect was a reduction in farmers' income. The increased cost of pumping led to demand of free electricity which again is recipe of further deterioration of situation.

Road Map for Future

If we take proper action, the situation is still reversible, although few experts opine that in few areas it has gone beyond reversal. It should be two pronged: Demand Side Management and Supply side management

Demand Side Management

A. Agriculture: This sector uses more than 80% water and therefore requires attention to reduce

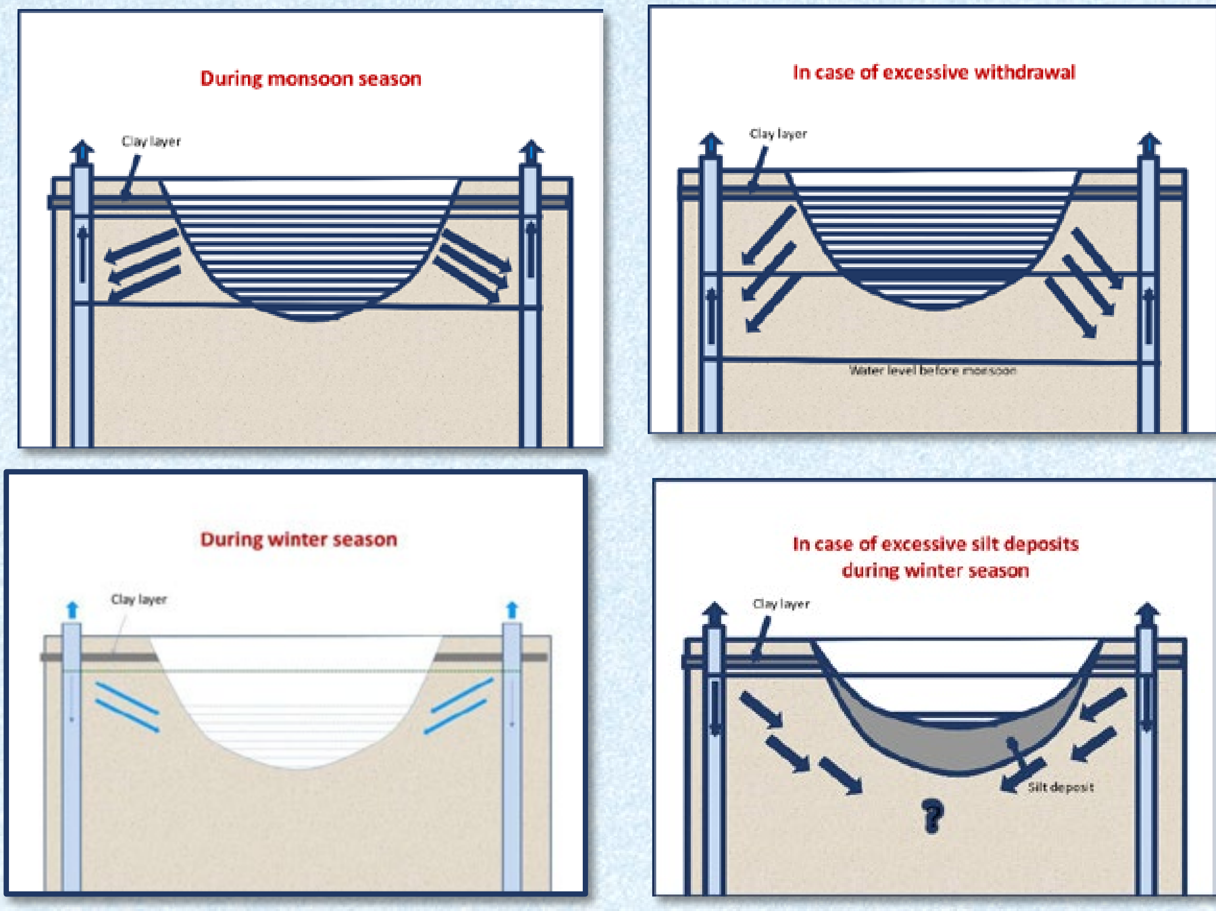

Fig. 5: River water groundwater level continuum conditions during different situations

demand by improving irrigation efficiency, mainly conveyance and application efficiency. Although pressurized irrigation is cited as a solution for this but still pressurized irrigation covers just 20% of net irrigated area with both drip and sprinkler sharing equal honours. Thus, for significantly reduce water demand, there is an urgent need to focus on improving the efficiency of surface irrigation by improving conveyance and application efficiency. The following steps can be taken to achieve this.

a. Reduce conveyance losses by shifting to piped conveyance

Unlined channels are common in groundwater irrigated areas although use of flexible pipe has gained currency. Few state governments like Bihar are giving subsidy over it but low life of it is a major handicap. By an estimate, the conveyance efficiency with unlined earthen channel ranges between 60% to 75% depending upon type of soil. In sugarcane belt of Muzaffarnagar it was found around 66% with about 800 mm loss in one irrigation season (Anonymous, 2014). Similarly at IIWM, Bhubaneswar, conveyance efficiency has been found 75% and application efficiency at 62% (Srivastava et al., 2010). Normally underground pipeline network is recommended for a deep tubewell either government owned or cooperative but experience at Muzaffarnagar has shown that laying underground pipeline of 150 m for individual tubewells commanding about 2-3 ha is quite feasible as it not only minimize the conveyance loss but also increase cultivated area by 1%. Given the cost of land @ Rs 50 lakhs per ha, cost of land compensate for cost of pipeline. Further, there is huge saving in electricity consumption. It has been estimated that replacing open earthen channel by underground pipeline in sugarcane fields of U.P. when conveyance efficiency is about 66% will result in annual saving of 1250 kWH per ha (Srivastava, 2023). If we assume 90% of sugarcane area of U.P i.e. about 20 lakh ha is covered by underground pipeline, a staggering saving of 250 Crore units of electricity worth Rs 1750 Cr can be saved annually with an investment of about Rs 10000 Cr which means that investment will be paid back in 6 years while life of underground pipeline is about 20 years. This does not include additional 20000 ha area of sugarcane which will produce sugarcane worth 600 Cr.

b. Increase application efficiency

Normally, there are three surface irrigation methods: check basin, furrow, and border irrigation. The design parameters of these three irrigation methods were developed about 50 years ago(Michael, 2011; Murthy et al.,2009). However, they were designed for a different land holding environment when land holdings were large as the average length of borders and furrows has been shown to be 100 m to 300 m. With shrinkage in land holdings and therefore individual plot size, there is a need to revisit design parameters to answerthe following questions: (i)what should be optimal stream size for these different sizes of furrow/ border/check basin lengths? (ii) what should be size optimal for stream size available (iii) what should be cut off time for these different lengths and (iv) what will be benefit in terms of irrigation if alternate furrow irrigation is used with these well laid irrigation methods. It has to be reverse engineering to estimate optimal solution for given plot size and size of stream available. This will improve application efficiency significantly. In addition to this, the laser levelling has to be adopted on large scale as levelling improves application efficiency significantly. The significant advantages are saving 22–33 per cent of water in irrigation and a 9–12 per cent increase in crop productivity (Pawan Kumar, 2017). If we see in energy terms, this means about saving of 1000 kWH per ha irrigated area.

c. Development of automated irrigation systems for surface irrigation

The labour cost increases exorbitantly for night irrigation especially for winter crop. In tubewell irrigation, availability of electricity during night makes it a compulsion to do night irrigation. Rising labour costs in rural areas make night irrigation less monitored, further reducing already low irrigation efficiency. Over irrigation also leads to nitrogen leaching and poor productivity. Automation will lead to system operation with no or just a minimum of manual intervention besides the surveillance. Pramanik et al (2021) has initiated work on it but it need intensification to develop an inexpensive, rugged model.

d. Research on improved irrigation pumps

A study at RPCAU, Pusa Bihar has indicated that pumping efficiency of pumps being used is much lower than desired or design efficiency. The pumping efficiency increases as the size of the pump decreases. The pumping efficiency varied from 50.2 to 58.5 % for 3hp pump, 37.9 to 47.1 % for 5hp pump, 29.3 to 31.7 % for 7.5 hp, 24.8 to 25 % for 20 hp and Pump and 23 % for 33hp submersible pump. Surprisingly, this situation is same for last 20 years as efficiency reported by AICRP on Pump for Jabalpur centre in 2004 (my observations during visit to JNKVV, Jabalpur) showed almost same results. There is little work on this aspect as all stakeholders have no interest on efficiency. Manufacturers have a captive market, farmers pay fixed energy or nil charges, and nobody tells the government about this dismal situation. This situation needs to be addressed at suitable forum to avoid further drain on our energy sources.

B. Domestic: With improvement in living standard and implementation of schemes for toilets and Har Ghar Nal, demand for this sector is going to increase significantly

a. Policy decision on double chamber flush system to make it less expensive

In 2003, CII organized a one day workshop on water use scenario in domestic sector. A major issue flagged was the system design for flushing, and it was decided to improve the design to have double chamber flushing systens. Presently high end systens have double chamber but cost is still prohibitive for a large section of society. Thus, suitable design and policy decision on taxation need to be taken to make it more affordable.

b. Improved designs of taps and showers

There is scope of improving design of taps and showers to increase their efficiency especially low end products. Suitable research on design and taxation policy should be undertaken to reduce leakage etc.

C. Industry: Until recently, very little attention has been paid to water consumption, especially metallurgy. However, with increasing industrialization, the efficiency of industry's water usemust be considered. Here data of water use for two major metallurgy industry has been illustrated to show the water use scenario in industry.

a. Water Use in Steel Production

Steel industry is a major consumer of water. A view of water use in different steel plants show that there is huge variation in water consumption per unit steel production. While Rourkela plant consumes 68 m^3 per tonne, Bokaro and Durgapur consume 57 and 47 respectively. On the other side, TISCO Jamshedpur consumes just 25 m^3 per tonne, which is 28 and 32 for Vizag and Bhilai plant. This indicates that all industries' water audits should be carried out and steps be suggested to reduce water requirement.

- Water use in Aluminium Production

Data available for water use in Aluminium production is very sketchy. In India, it is shown at few places as 20-22 m^3 per tonne while globally it is shown 9.2. It shows poor importance accorded to water consumption in industry. Thus, it is essential that water consumption data be collected properly and suitable interventions be suggested to reduce water consumption.

Supply side management

Supply side management will mainly include enhanced recharge of groundwater and use of gray water. Although few researchers have suggested that some aquifers have become irreversible, in most areas, aquifers can be recharged with excess runoff. With climate change creating high intensity rainfall, the natural groundwater recharge is under risk of getting reduced with increased runoff. The traditional method of enhancing recharge through water harvesting systems is not very practical in view of land shortage and therefore researchers have adopted subsurface methods to develop recharge systems which include injection well or recharge well, recharge pit and shafts, dugwell recharge, borewell flooding and natural opening/cavity filling. Two recharge systems developed for field use with recharge pit and shaft method are presented here:

a. Design developed at CSSRI, Karnal

The technology is the Recharge Filter (Fig. 6). The recharge filter consists of layers of coarse sand, small gravel, and boulders in a small brick masonry chamber. The structures involve passing excess rainwater under gravity through a bore well to subsurface sandy zones coupled to the recharge filter. The recharge structures can be installed at any low-lying location prone to surface water flooding. However, the design has problem of clogging in recharge structures: (i) clogging of the recharge filter, particular of the upper sand layer and (ii) clogging of underground sandy layers of recharge shaft and semi- spherical cavity in recharge cavity. Depending upon the sediment load of the flood water (permissible turbidity level: 5- 10 NTU), all filtering materials in recharge chambers may need to be emptied out and thoroughly cleaned and filled

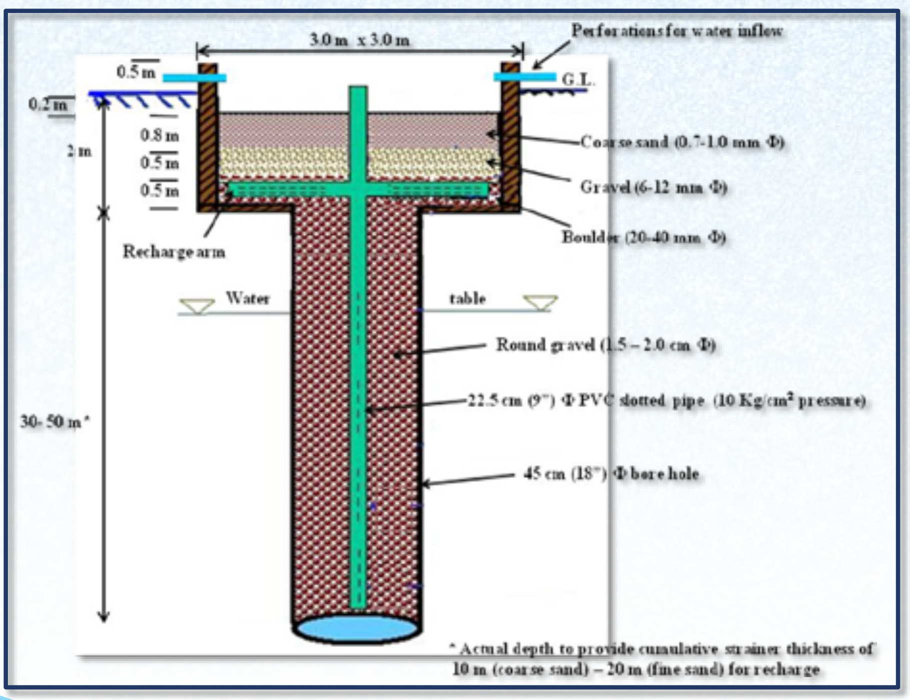

Fig. 6: Design features of groundwater recharge shaft (CSSRI, Karnal)

back every year. This will require clean 10.8 cum of material equivalent to 1.5 truck load of sand, gravel & boulders which will require both labour and water.

b. Design Developed at RPCAU, Pusa, Bihar

A design developed by RPCAU, Pusa, Bihar by the author uses an online filter to avoid large quantity of filter material and it has been proved very successful. It requires just 50 sq m of space and has annual capacity of recharging 5 ha m i.e., 5 Cr litres of water annually by a single unit. The cost of one unit is around 2.5 to 3.0 lakhs. The filter material can be cleaned by dismantling the pipeline and clean the filter material whose amount is quite small (Fig. 7).

Utilization of Gray Water

It has been found that about 70- 80% of water used by domestic sector is converted to waste water i.e. gray water and is released to river system. Presently about 350 Class I and Class II urban centres having >50,000 population generate around 38,254 million litres per day (mld) of waste water out of which only 11,787 mld, (31 per cent) get treated. The projection for 2050 is 170,000 mld (62 BCM) by 2051. This gray water can be used for irrigation with just filtering and simple treatment. Umra et al (2023) have found that use of gray water can ease problem of water shortage. Although a lot of work has been done, but here only two works and one concept is being presented here:

a. IARI New Delhi Model

This model is a decentralized waste water treatment based on engineered wetland technology (Fig. 8). The system treats 2.2 MLD of waste water with an annual irrigation potential of 132 Ha. The source of the waste water is a nearby drain carrying waste water from the adjacent Krishi Kunj and Loha mandi Colony. The treatment plant has capacity of treating 2.2 million litres per day with O & M cost of just Rs 1335/- per day and capital cost of 1.2 Cr. However the biggest constraint is size of area it requires which in this case is 1.42 ha. The cost of land as well as availability of such area in an urban area is quite prohibitive.

ICAR-IIWM Bhubaneswar Model

Studies at Indian Institute of Water Management, Bhubaneswar has resulted in design of a simple on line waste water filter which can be used while pumping Gray Water for irrigation. If used for peri urban agriculture this can replace precious groundwater (Fig. 9).

Concept of in situ waste water treatment

A major constraint of urban waste water treatment is lack of land available in urban landscape. With this in view, an in situ treatment system was conceptualized at ICAR-IIWM, Bhubaneswar. This system involves construction of series of gabion filters in nalas itself. The design has been made in such a way that each filter takes care of a part of flow. The remaining part is directed to flow through next filter with again a part going unfiltered (Fig. 10). A methodology using channel hydraulics parameters has been developed to determine the width of channel covered by filtered. The design parameters have to be percent of nala width to be covered by filter, gap between two filters. This will be dependent upon peak time discharge,

Fig. 7: Overview of drainage cum recharge structure developed at RPCAU, Bihar

Fig. 8: Schematic view of treatment plant at IARI, New Delhi

Fig. 9: Schematic view of filter developed by ICAR-IIWM, Bhubaneswar

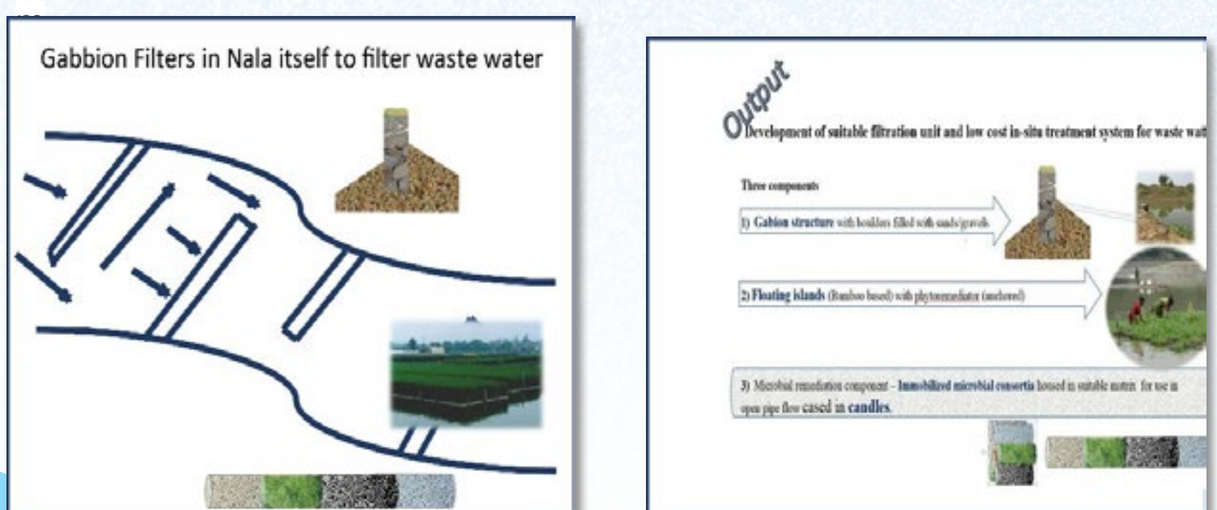

Fig. 10: Schematic view of in situ filtration system for waste water management

nala characteristics. Once water is filtered, floating wetland can be created in the drain itself with aquatic macrophytes such as water hyacinth (Eichhornia sp.), duckweeds (Lemna sp., Spirodella sp.), smallwater fern (Azolla sp.), and water lettuce (Pistia sp.) to remove heavy metals from wastewater. This concept was given a shape in campus itself but it could not be completed due to widening of road.

Final Goal

For making our future safe we should create a Water Positive Aquifer i.e. supply should be more than demand. For this an unit area has to be taken. This unit can be a city, block, or any administrative unit. We have to a) Estimate total water demand recent and future; b) Estimate present groundwater recharge; c) Estimate available municipal wastewater i.e. Gray Water; d) Estimate runoff available for recharge after accounting for environmental services. Select a package of technologies suitable for region and prepare a plan for enhanced recharge, use of groundwater and areas where use efficiency can be increased to make it a positive aquifer. Let us remember that water cycle and life cycle are interdependent.

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PERSPECTIVES ON HYDROLOGIC EXTREMES WITH A CASE STUDY FROM THE CHAMOLI BASIN

Venkataramana Sridhar

Virginia Tech, Blacksburg, VA 24061, USA

Introduction

In the context of river basins like the Ganges, Cauvery, Krishna, Godavari in India, and Mekong in Southeast Asia, which are experiencing transformations in their physiography, land cover, and facing the effects of both natural and human-induced climate change, it becomes exceptionally valuable to conduct an assessment of the water cycle. This assessment takes on added significance when it is driven by the goal of integrating human-water systems, representing a scientific endeavor that seeks to comprehend, describe, and measure the movement and storage of water resources across various temporal and spatial scales. Studying hydrologic extremes in these basins require data, which is generally a limiting factor. Studies investigating extreme precipitation events (EPEs) use surrogate variables to relate the impacts of EPEs which pose significant threats to human life, agriculture, and infrastructure, as they can lead to flash floods and landslides. The increased transport of atmospheric moisture driven by a warming climate is expected to result in a higher frequency of EPEs. Notably, in the Asian region, there is a discernible correlation between human activities and the heightened intensity of extreme precipitation events in recent years.

Disasters

The Indian monsoon is a meteorological phenomenon that holds immense significance for the Indian subcontinent. It is a seasonal wind pattern that brings a heavy influx of moisture-laden air from the southwest during the summer months, typically from June to September. This wind pattern is responsible for the iconic monsoon rains that play a vital role in the region's climate and agriculture. However, while the Indian monsoon is crucial for replenishing water resources and sustaining agriculture, it also has a downside - the risk of flooding. The monsoon season can bring torrential rains, resulting in widespread and sometimes devastating flooding across various parts of India. Efforts are ongoing to better manage and adapt to monsoon-related flooding in India, including infrastructure improvements, floodplain zoning regulations, and disaster preparedness and response strategies. It's crucial for India to continue addressing this annual challenge to protect lives, property, and the country's agricultural and economic stability.

The Chamoli landslides, a devastating natural disaster that unfolded in February 2021, sent shockwaves through the northern Indian state of Uttarakhand, particularly in the Chamoli district (Fig. 1). This catastrophic event was primarily triggered by an avalanche and a glacial lake outburst flood (GLOF). The breaking of a glacier set the disaster in motion, causing a rapid and overwhelming surge of water, debris, and rocks to cascade downstream. The Chamoli landslides led to a significant loss of life, injuries, and the displacement of communities living along the riverbanks, as villages and settlements bore the brunt of the devastation.

One of the most striking aspects of this disaster was the extensive damage inflicted upon hydropower infrastructure. The torrents of water and debris reached the Tapovan

Fig. 1: The floods in the Upper

Fig. 2: Pre-monsoon low flow condition in the Grand Anaicut Dam, Cauvery Basin, Tamil Nadu

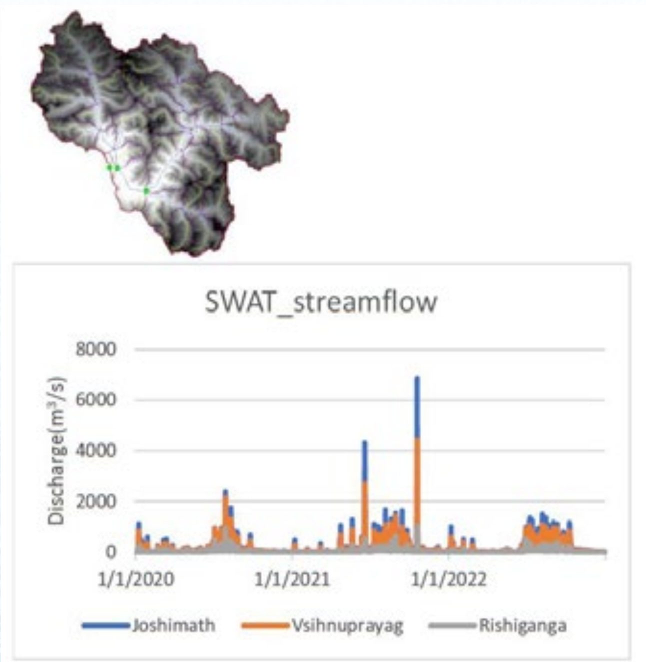

Fig. 3: Flow analysis in the Chamoli basin using the SWAT model

Vishnugad Hydropower Plant and the Rishi Ganga Hydel Project, resulting in the destruction of vital infrastructure and machinery. This tragic event emphasized the vulnerability of glaciers in the Himalayan region due to climate change and underscored the urgent need for early warning systems and disaster preparedness in areas susceptible to such catastrophic events.

The Godavari and Cauvery river basins in South India are vulnerable to monsoon-related flooding. During the monsoon season, heavy rainfall in the catchment areas can rapidly rise water levels, inundating nearby villages and farmlands. These floods can cause significant damage to homes, infrastructure, and agricultural fields, often resulting in the displacement of communities. In addition to the immediate human and economic costs, these floods can also lead to soil erosion and water contamination.

Conversely, these river systems also experience droughts, especially during periods of weak monsoons or extended dry spells (Figure 2). Droughts can have severe consequences for agriculture, as water scarcity affects crop yields and can lead to food shortages. Moreover, water scarcity impacts drinking water supplies and can lead to conflicts over water resources. These droughts, combined with increasing water demand due to population growth and industrial expansion, underscore the need for effective water management strategies in the Godavari and Cauvery basins.

Efforts to mitigate the impacts of floods and droughts in these river systems include the construction of dams and reservoirs for water storage and flood control, as well as the implementation of water conservation and management practices. These measures aim to balance the availability of water resources and ensure sustainable usage while reducing the vulnerabilities of communities in the region to the vagaries of extreme weather events. The Godavari and Cauvery river systems serve as a stark reminder of the challenges posed by water management in a country with a rapidly growing population and a changing climate.

Modeling Approach

Generally, a combination of models are used to assess the peak flows and low flows. For the Chamoli basin, we used the SWAT model to assess the flood flows. The Soil and Water Assessment Tool (SWAT) is a distributed hydrological model. SWAT simulates the movement of water, sediment, and nutrients in large watersheds. SWAT is designed to provide estimates of the long-term impacts of land management practices on Water quality, erosion, and sediment transport. In this project, SWAT model was used to simulate the streamflow (2020-2022) in the Chamoli watershed. To delineate the SWAT model's watershed, ASTER DEM, land use data from IWMI (International Water Management Institute), and soil data from FAO (Food and Agriculture Organization) were used as input data. The streamflow in the Joshimath area generally followed a similar pattern to the precipitation. The maximum daily flow occurred in 2021 with a value of 6627 cm3/s, while the minimum flow was observed in 2022 with a value of 0.04 mm. This suggests that the significant amount of rainfall in 2022 had an impact on the streamflow. Correlation analysis between precipitation and streamflow revealed R values of 0.9 for Joshimath, 0.86 for Vishnuprayag, and 0.91 for Rishiganga, indicating a strong correlation between streamflow and precipitation. To improve the flow analysis, we implemented the HEC-RAS model with high-resolution drone images with a spatial resolution of 10m and ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) DEM (Digital Elevation Model) data with a spatial resolution of 30m. This combination of data allowed us to enhance the accuracy and precision of the HEC-RAS model, as the higher spatial resolution provided more detailed information for simulating water flow dynamics (Fig. 4). Similarly, for the Cauvery basin we evaluated evapotranspiration over the basin and assessed how water availability could impact the crop yield. However, the results are not included in this article.

Summary and Conclusions:

The Chamoli flooding, which occurred in February 2021, resulted from an avalanche and glacial lake outburst flood in the Indian state of Uttarakhand. Triggered by a glacier breaking off, it sent a surge of water, debris, and rocks downstream, causing significant loss of life and infrastructure damage. The

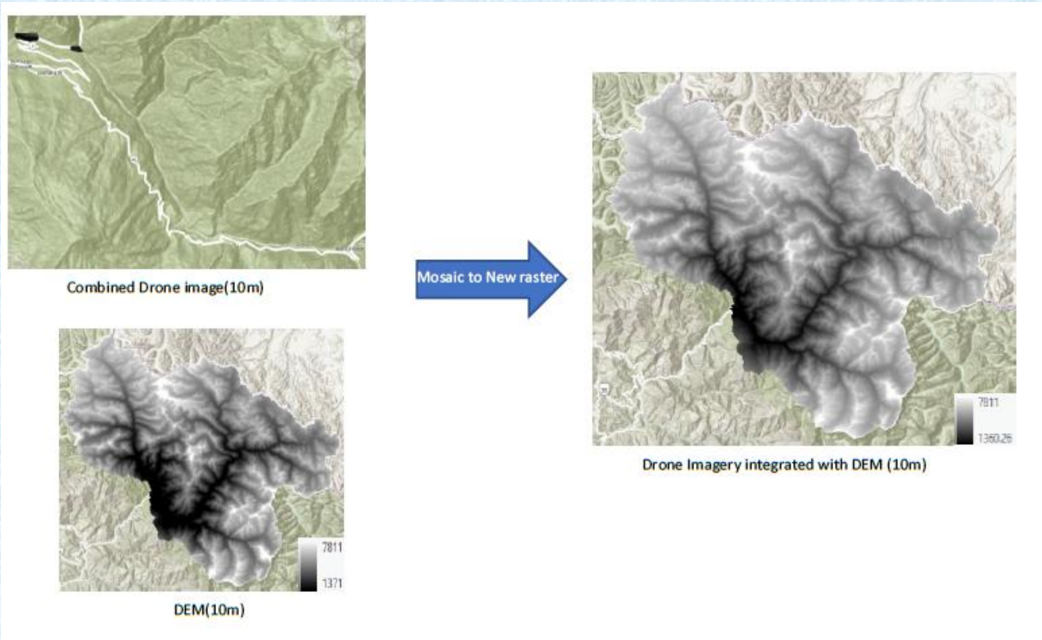

Fig. 4: Integration of drone-imageries for flood flow analysis in the Chamoli basin

event underscored the vulnerability of Himalayan glaciers to climate change, emphasizing the need for early warning systems and disaster preparedness in regions susceptible to such devastating natural events. It is also important to customize the hydrologic and hydraulic modeling analysis with local data to predict the flood flows better.

Acknowledgements

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NATURAL RESOURCE MANAGEMENT THROUGH INNOVATION IN MECHANIZATION, DRONES, AND ROBOTICS UNDER CLIMATE CHANGE SITUATION

Indra Mani Mishra

Vice-Chancellor
Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani – 431 402 (M.S.)

Introduction

As the global population continues to grow and the demand for food rises, the agricultural sector faces the challenge of increasing productivity under climate change scenario by using optimum consumption of natural resources. In India, a country with a significant agrarian economy, the need to enhance farming practices with efficient utilization of natural resources is paramount. Innovative technologies such as farm mechanization, drones, and robotics have the potential to revolutionize farming practices in India, offering a sustainable approach to natural resource management. Like other economic sectors, agriculture is increasingly affected by the digital revolution. The use of advanced technologies results in precise matching of agricultural inputs with needs and thus significantly increases profitability while reducing resource wastage. By harnessing technology as a sustainable and scalable resource, the agriculture of the country can be taken to new heights, all while preserving and efficiently managing its natural resources. Conquering agricultural challenges requires breaking through the weakest link of the food chain by using technology, with digitization as a keystone. In July 2021, the Honourable Prime Minister addressed chiefs of the top 100 technological institutes, emphasizing the importance of agricultural inventions and innovations. Agriculture was listed among key sectors like Defence, Education, Health, climate change, and cyber security. He also urged scientists to provide solutions to various issues in agriculture through modern biotechnology, artificial intelligence, blockchain technology, and drone technology to counter issues like hunger, poverty, and malnutrition. Future agriculture will be led by knowledge, technology innovation, and skill. In fact, mechanization and automation in agriculture have been recognized as one of the top 20 inventions of the 20th century worldwide. Traditional farming practices often rely on manual labor and outdated methods, leading to inefficiencies, resource wastage, and yield variability. The integration of advanced technologies like mechanization and automation, drones, and robotics holds the promise of addressing these challenges and propelling Indian agriculture towards greater productivity and sustainability, all while effectively managing its natural resources under climate change situation.

1. Innovations in Farm Mechanization

Agricultural mechanization is pivotal for the modernization and commercialization of the sector. It enhances efficiency, lowers cultivation costs, supports value addition, and helps in adapting to climate change. In India, agricultural mechanization is expected to grow rapidly due to national and global driving forces. However, despite the progress, the level of farm mechanization in India remains relatively low compared to other countries. In India, only 40-45% of farming operations are mechanized, while in the US, it is 95%, in Brazil, 75%, and in China, 57%. India's journey into farm mechanization began in 1914 when the first tractor was imported. Today, India is the world's largest market for tractors, with an annual production of over 1.1 million tractors. This progress notwithstanding, there are challenges such as skill shortages and a lack of awareness among farmers about technology and machinery management. To overcome these obstacles and take agricultural mechanization to the next level, there is a need to focus on integrating science and technology into farm mechanization.

Key interventions for bringing innovations in agricultural mechanization include:

- Mapping dynamic changes in agricultural practices and designing equipment for all operations.
- Manufacturing operator-friendly equipment to minimize farmer anxiety about skill requirements.
- Ensuring the quality and durability of equipment to reduce the 'Cost of Ownership' in the long run.
- Developing a 'Responsible & Accountable' Service Network.
- Ensuring clusters of an eco-system for quick availability of genuine spare parts.
- Leveraging the strong network of tractor dealerships for effective penetration of agricultural equipment. These dealerships can be used as 'Knowledge Springboards' to educate and demonstrate advanced agricultural equipment.
- Encouraging agrochemical manufacturers to engage in 'contractual collaboration' with farmers, making advanced crop care equipment available at the farmer's doorstep for all crop care applications without human intervention.

- The government, State Agricultural Universities (SAUs), and corporate sectors can conduct awareness campaigns to educate farmers about the benefits of mechanization. This will help increase the demand for machinery and create a market for the mechanization industry.
- Tractor training centers, Krishi Vigyan Kendras (KVKs), and the industry should be made responsible for training young farmers, owners, and operators on how to select, operate, and service farm machinery. They should also provide information on developments in mechanization, including the availability of new and better farm equipment for different applications.
- Strengthening front-line demonstrations of farm machinery and providing hands-on training to users of new-generation farm machinery to encourage the extension and adoption of farm power.
- Collaborative efforts between government institutes, private companies, and farmers' groups are necessary to boost agricultural mechanization. Custom Hiring Centers for farm machinery can be especially useful, and the Indian Council of Agricultural Research (ICAR) institutes and SAUs can offer short courses that address skills shortages on the demand side.

2. Climate-Smart Agriculture through Innovative Water and Energy Saving Interventions

Sustainable food production with judicious use of water, energy, and land has become a matter of global concern due to environmental security under changing climate conditions. Rainfed agriculture is crucial to India's economy and food security, with more than 60 percent of the cultivated land still under rainfed agriculture. To sustain yield in rainfed systems, conservation of costly inputs and resources like soil, water, land, and power is essential.

Innovative farming techniques, such as broad bed furrow (BBF) technology, serve the purpose of in-situ moisture conservation as well as drainage. Mechanization contributes significantly to conservation agriculture because of its timeliness in farm operations. VNMKV has developed a multipurpose Broad Bed Furrow (BBF) planter for rainfed agriculture, which accomplishes bed preparation, sowing, fertilizer application, seed covering, and weedicide application in one go. Machinery powered by non-conventional energy sources is gaining importance to supplement the use of fossil fuels. India is endowed with vast solar energy potential, and solar photovoltaic power can effectively be harnessed, providing huge scalability. VNMKV has developed a multipurpose solar energy cart that supplies power to spraying units, DC pumps, and lighting systems.

Initiatives at VNMKV Parbhani for energy-smart Indian agriculture

VNMKV has signed a MoU with the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH (Germany) for collaborative research and development of Agricultural Photovoltaic (AgriPV) technology. The research aims to devise executable crop cultivation strategies for selected crops under different Agrivoltaic structures to generate higher yields or higher revenues.

3. Digital Agriculture : Future Farming through drones and robotics

Digital Agriculture leverages the smart use of data and generally involves the processes of data creation and analysis, decision making, and implementation through management interventions. These processes are becoming increasingly computational, data-intensive, real-time, and precise. Today's main Digital Agriculture tools include cross-cutting technologies such as sensors and controllers and computational decision tools. Field-based activities are also enabled by technologies such as geo-locationing, communication (cellular, broadband, and others), geographical information systems (GIS), yield monitors, precision soil sampling, proximal and remote sensing, unmanned aerial vehicles, variable rate technologies and auto-steer, guidance, and robotics. With the country achieving sufficiency in food production, there is an immediate need for the agricultural sector to adopt cutting edge digital and precision agriculture technologies to improve input use efficiency and enhance farmers' profitability by increasing productivity, reducing cost of cultivation and adding value to farm produce. Drones are one such technology that have the potential to revolutionize the farming industry through need-based precise and variable input applications, leading to input saving, timeliness, reduction in cultivation cost, and ensuring farmers' safety from direct exposure to chemicals. Drones have proven to be among the most promising technologies emerging from the fourth industrial revolution. Drones can be used for targeted input application, timely diagnosis of nutrient deficiency, crop health monitoring, and rapid crop yield and losses assessment. The drones have capability to fly at low height (1m-3 m) over the crop canopy. This makes them suitable for spraying of crop protection chemicals as well as nutrients and is more adoptable compared to aerial spray. Unlike ground spraying, spraying through drones can be carried out when field conditions prevent movement of wheeled vehicles. It enables the timeliness of spray treatments without inflicting soil compaction. Drone based application in agricultural production system also saves input cost and environment. Due to theses associated advantages, the use of drones in agriculture has increased sharply in recent years worldwide for soil and field analysis, mapping and animal detection, and irrigation, crop spraying and planting. The drone technology has the potential to not only reduce the quantity of the inputs like pesticide, crop nutrients but also save environment and farmers from harmful exposure.It can effectively be used for timely spraying of crop inputs with minimum labour requirements. Drone is also helpful for spraying of crop nutrients and pesticides in hilly regions wherein it is difficult for other farm equipment to reach. Many startups, industries, SAUs and research institutions have started working on drone to harvest its potential in agriculture including soil and crop nutrient spraying. As the DGCA guidelines are available now, many companies have registered their products on Digital Sky Platform including agriculture drone. Lack of standard guidelines for use of drone in agriculture has been a bottleneck in popularizing drone based technologies in India. As the drones are being increasingly used for several agricultural operations, it was essential to develop SOPs that would facilitate application of different types of crop soil and crop nutrients using drones; and harness their potential for successful adoption of soil and crop nutrient spraying. The Standard Operating Procedure (SOP) for use of Drone application for crop protection in agricultural, forestry, non-cropped areas, etc. was released by Ministry of Agriculture and Farmers Welfare (MoA&FW, GoI) in December 2021. The was followed by release of crop specific Standard Operating Procedure (SOP) for the application of pesticides with drones in April, 2023. These SOPs will guide the stakeholders involved in safely and effectively controlling pest and disease by drone-based application.

Not only drone, use of AI in agriculture is also emerging especially in three major categories - agricultural robotics, soil and crop monitoring, and predictive analytics. Farmers in many developed countries use AI technologies for sowing seeds using drones, soil mapping, and commodity pricing. AI helps reduce the operational costs in farms by reducing dependence on manual labor and allowing agronomic expertise to make data-driven decisions. In India, work on use of AI and robotics for agriculture is at early stage and needs extensive field evaluation for reaping the real benefits of advance technology.

As our population continues to grow, our agricultural methods must grow with it. It is time to take advantage of the technology we have at our disposal to put food on our table and create sigh of relief for our farmers. Youth agripreneurs play a key role in the digitalization of the agricultural sector. There is increased interest in data-enabled farming and related services and many new entrants from the technology industry and start-ups. Vast data collection will drive the use of machine learning and AI and new models will need to be developed to make the data useful.

Initiative at VNMKV, Parbhani for Digital Agriculture

The Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani has taken initiatives to promote the digitalization of agriculture. The "Centre of Excellence for Digital Farming solutions for Enhancing Productivity by Robots, Drones and AGV's (DFSRDA)" under Centre for Advanced Agricultural Science and Technology (CAAST) has been established under World Bank sponsored National Agricultural Higher Education Project (NAHEP) of Indian Council of Agricultural Research (ICAR), New Delhi, Government of India, since 2019. The centre has been engaged in training PG and Ph.D. students and faculty members about advances in digital technologies. The centre has established an advanced basic engineering hardware and software setup such as Mechatronics, CAD/CAM/CAE, 3-D Printers and Instrumentation Laboratories for Agri-bots, Agri-drones and Agri-AGVs, and a holistic model has been developed to raise the standard of current agricultural education system that has been facilitating more jobs and entrepreneurship development among the youth and on par with the global agriculture education standards. The centre of excellence has created an advanced digital laboratory for students, faculty, and entrepreneurs to obtain a chain of knowledge to get the farming productivity solutions with the help of Agri-bot, Agro-drones, and Agri-AGVs (Automated Guided Vehicles) devices in four portfolio such as Climate based Digital Knowledge Support (CDKS), Centre Seed / Seedling Processing & Nursery (SSPN), Centre Smart Portable Machines (SPM) and Centre Food Processing Automation (FPA) Centre. With the help of these four functional areas, easy and necessary digital equipment for farmers have been developed under NAHEP. The MoUs has been signed for collaborative efforts regarding digital agriculture with many reputed national and international institutes including US universities and IIT-Kharagpur, IIT-Bombay etc.

One Year Professional Certificate Course on Drones, Robots, & AGVs in Agriculture

One professional certificate course will be launched under NAHEP at VNMKV, Parbhani, with the goal of educating youth about advanced digital farming technologies. The major focus of the course will be application of Agri-Drone, Agri-Bot, and Agri-AGVs. The course puts major emphasis on skills and vocational training to empower youths and enable them to start their own entrepreneurship ventures like custom hiring centre of digital technologies and devices. This course is formulated to acquire knowledge of various digital technologies and its intervention in agricultural as well as industrial field. The VNMKV, Parbhani signed MoU with M/s IoTechWorld Avigation Pvt. Ltd, Gurugram, Haryana to develop and form RPTO (Remote Pilot Training Organization) for developing Agri-Drone Pilots in Maharashtra state.

Conclusion

The path to sustainable natural resource management under climate change's shadow is intricately linked with automation in mechanization, robotics, and drone technology. These innovations hold the potential to transform agriculture in India, making it more efficient, productive, and resilient in the face of changing environmental conditions. As the world grapples with the daunting challenges of a growing population and a changing climate, integrating these advanced technologies is not just a choice; it's necessary to secure a future of food security, prosperity, and resource sustainability. Innovations in mechanization, drones, and robotics have the potential to revolutionize farming practices in India. By modernizing traditional methods and addressing challenges in agriculture, these technologies can contribute to increased yields, resource efficiency, and sustainability. The journey towards an advanced agricultural sector will require collaboration between policymakers, researchers, industry and farmers to ensure that these technologies are accessible, affordable, and effectively integrated into India's farming landscape. With the great efforts of research Institutions, vibrant industry and very conducive government policies, agriculture as a whole and mechanization in particular has grown exponentially in the country. Digital tools of mechanization and automation of operations will attract young talented youths, startups, professional engaged in NGOs and FPOs towards agriculture which will finally lead to dream agriculture of India 2047.

UNIVERSAL MANAGEMENT OF NATURAL RESOURCES FOR LIVELIHOOD IN THE CONTEXT OF CLIMATE CHANGE

Suraj Bhan[1*] and Sanjay Arora[2]

[1]President, Soil Conservation Society of India, New Delhi*
[2]Vice-Chair, IUSS Commission 3.6 & Principal Scientist, ICAR-CSSRI, RRS, Lucknow, India

Introduction

Management of land and water is critical for realizing the objective of meeting food security in the context of climate change. Global climate change adversely affects every aspect of human life, amplifies the vulnerabilities of natural resources, and presents significant hurdles to the well-being of communities worldwide. Managing these resources sustainably and equitably is crucial for ensuring not only the survival of our planet but also the prosperity of present and future generations. There is a global consensus that the current climate is changing and for real. Agriculture is one sector of the economy that is directly affected by climate change and climate variability, mainly due to adverse changes in natural resources. There is growing research and knowledge by experience about methods of managing natural resources for their sustainable use. Also, over the years, adaptive techniques to manage the adverse impacts on crop production have come up, which need to be popularized for adaptation by farmers.

According to an estimate, about 147 million ha is affected by various degradation, which is further exposed severely by floods, droughts, prolonged heat waves and changes in rainfall patterns. Thus, steps must be initiated to minimize the risk of additional degradation due to adverse impact of climate changes. The alarming challenge of climate change has also been noticed in recently held G20 meeting during September 9-10, 2023 in Delhi with the theme "Vasudhaiva Kutumbakam-One Earth, One Family and One Future". Inparas33 and 34 of Delhi Declaration of G20, it has been the consensus of all the participating countries to urgently accelerate the suitable actions to address environmental crises and challenges, including climate change. It is recognized that the impacts of climate change are being experienced worldwide, particularly by the poorest and the most vulnerable including in Least Developed Countries (LDCs) and Small Islands Developing States(SIDS). Mindful of their leadership role, they reaffirmed their steadfast commitments in pursuit of the objective of United Nations Framework Convention on Climate Change (UNFCCC), to tackle climate change by strengthening the full and effective implementation of the Paris Agreement and its temperature goal, reflecting equity and the principle of common but differentiated responsibilities and respective capabilities, in light of different national circumstances (The Paris Agreement 2015, participated by 196 countries, resolved to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius).

The concept of universal natural resource management needs to be adapted as a strategy to address the adverse effects of climate change. It places particular emphasis on sustainable resource management with a critical focus on conserving soil and water resources. The paper explores how adopting a holistic approach to resource management can lead to more resilient livelihoods and a sustainable environment. It seeks to answer essential related questions: What does universal resource management entail? How can it be implemented globally? What are the associated benefits and challenges? By examining the intricate connections between climate change, resource management, and livelihoods, this paper aims to illuminate a path toward a more resilient and equitable future.

Impact of global climate change

Unpredictable climate change is threat to the sustainable development of natural resources and restoration of adverse impacts of climate change. Every day, there is alarming news about natural calamities hitting some regions. The impacts of various adverse weather events are summarized as given in Table 1.

Resultant impacts of the climate change:

The impacts of climate change result in severe famine or heavy floods, loss of life, loss of agriculture crops and animals, loss of livelihood, increased risk of disease outbreaks, damage to infrastructure and communication, particularly of rural areas, setback to social and economic developments and emergence of social turmoil with increased rural-urban divide, pushing farmers back to below poverty line, impact in productivity of various crops, thereby creating a challenge to food security etc.

Some glaring global damages due to climate change

Huge damages are due to climate change all over the world. Climate change has led to an average annual global loss in infrastructure, as estimated by the Coalition for Disaster Resilient Infrastructures (CDRI) at $850 billion. Some specific damages are given below:

Table 1: Impacts of Climate Change

Adverse Weather Events	Impact
Increased Temperature	Low crop productivity- crop failures
Hot and Cold wave	Low productivity in livestock, fisheries and poultry
Unseasonal frost	Washing away of fields or waterlogging.
Recurrent droughts in many areas despite good monsoon.	Livestock- poultry – cattle -loss
Recurrent delayed rain	Deterioration quality of harvested produce and loss in quality and quantity.
Increased delay between two spells	Increase attack of pest.
Single heavy rain episodes in isolated places	New viral fiver in livestock which also affects humans e.g. bird flu-Swine flu
Cyclone	Sprayed fertilizer or pesticides lose impact.

- In the US alone, nearly 1,000 tornadoes have killed many people and inflicted $9 billion in damage.
- The 2010 heat wave in Russia killed hundreds of people and led to a 40% fall in the harvest of food grains.
- Floods in Australia and Pakistan killed thousands of people and devastated agricultural lands.
- Recurrent droughts in China have eroded millions of acres of farmland and caused the loss of lives.
- Recurrent and continuous famines in Ethiopia-Somalia and riots for food by hungry millions.
- Frequent recurrence of floods in South East Asia, Philippines, Indonesia, Thailand and in other countries.
- According to an estimate, India suffered losses of 37 billion dollars in 2018 due to climate change.

Universal Management of Natural Resources

Universal resource management is a concept that signifies the coordinated and responsible governance of natural resources, transcending geographical boundaries to ensure their sustainability for current and future generations. It acknowledges the intrinsic link between ecosystem health and human well-being, recognizing the pressing need for global cooperation in addressing the shared challenges posed by climate change. This approach promotes the idea that nations, communities, and individuals share the responsibility for preserving and managing natural resources, necessitating collaborative efforts to achieve common goals. It underscores the importance of collaboration, breaking down political and geographical barriers to foster collective action for the greater good, as the impacts of climate change are not limited to political boundaries.

The implementation of universal resource management hinges on a combination of crucial factors. International frameworks and agreements, such as the Paris Agreement and the Sustainable Development Goals, offer essential guidance and principles for global resource management endeavours. Governments, non-governmental organizations (NGOs) and local communities play pivotal roles. Each Government has responsibilities for enacting policies and regulations that align with the tenets of universal resource management, while NGOs often serve as advocates for sustainable practices and catalysts for cooperation. The local communities are integral to the successful execution of this concept, bearing the impact of resource management decisions daily. Building capacity for resource management at all levels, from grassroots communities to international organizations, is a cornerstone of effective and informed decision-making. The benefits of universal resource management are manifold. It offers an opportunity for:

- Enhanced resilience to climate change impacts, as the pooling of resources and knowledge can better equip nations and communities to adapt to these challenges.
- Reduction in resource conflicts, as collaborative management reduces the likelihood of disputes over shared resources, fostering peaceful coexistence.
- Increased access to clean energy and water resources, as universal resource management facilitates the equitable distribution of these vital elements, improving living conditions for many.
- Poverty reduction and improved livelihoods, particularly in resource-dependent communities, through the creation of economic opportunities.

Challenges of Universal Resource Management

There are many and various challenges of universal resource management that need to be considered during planning and implementation by the concerned countries. Some of the core challenges are given below:

- Political and institutional barriers can impede progress by hampering the alignment of interests among multiple nations and stakeholders.
- Equity and social justice concerns arise when balancing diverse communities' and nations' needs and rights, potentially leading to social injustices.
- The delicate task of striking a balance between local resource needs and global sustainability goals, as local priorities may sometimes clash with broader objectives.
- Financing and resource allocation challenges are characterized by the intricate process of fairly and effectively allocating resources that is both financial and trained manpower which are often constrained by resource scarcity and economic disparities.

In essence, universal resource management signifies a fundamental shift in how the world approaches the conservation and governance of natural resources. It champions the values of cooperation, shared responsibility and sustainability as essential elements in addressing the global challenges presented by climate change and resource depletion. In the face of climate change, adopting a universal approach to managing natural resources is crucial for safeguarding livelihoods, particularly in regions with high vulnerability to climate-related impacts. India, a country known for its agricultural dependence and susceptibility to climate variability, serves as a pertinent case study. The concept of universal resource management transcends geopolitical boundaries and emphasizes shared responsibility, cooperation, and sustainability. This translates into an urgent need for sustainable practices prioritizing soil and water conservation in India.

Sustainable Natural Resource Management

Sustainable natural resource management under Global Climate Change encompasses several key components. At its core, it involves the equitable and responsible utilization of natural resources while ensuring their integrity for the benefit of future generations. This approach acknowledges the intricate interplay between ecosystems and human well-being. Moreover, it recognizes that climate change significantly impacts various natural resources, such as water, land, forests, and biodiversity. These changes necessitate adaptive management strategies and ecosystem-based approaches. Community participation and empowerment also play a pivotal role in sustainable resource management, fostering collaboration and ownership. Furthermore, international agreements like the Paris Agreement, Sustainable Development Goals, and the Convention on Biological Diversity provide essential policy frameworks to guide global efforts in this direction.

There is a close relationship between climate change, limited global water and soil resources, population growth and food security (Fig. 1). As climate change impacts the world's soil and water resources, it threatens to negatively impact food production (i.e., decrease food production and/or food production potential). As the climate changes, conservation practices have the potential to help us achieve maximum sustainable levels of food production, which will be essential to efforts to feed the world's growing population. Good policies/practices for soil and water conservation will positively impact soil and water quality, soil productivity, and efforts towards achieving and/or maintaining food security. These good policies/practices will contribute to climate change mitigation and adaptation. Poor policies/practices for soil and water conservation (or a lack of policies/practices) will negatively impact soil and water quality, soil productivity, and efforts toward achieving and/or maintaining food security (Delgado et al., 2011).

The Impact of Climate Change on Natural Resources

Climate change is altering ecosystems, weather patterns and the availability of essential resources such as water, arable land and biodiversity. The consequences are far-reaching, affecting food security, water access, and the stability of ecosystems. Understanding the multifaceted impact of climate change on natural resources is the first step in crafting effective management strategies.

Impact of Climate Change on Water Cycle for Agriculture

In India, even without climate change, underground water resources are reducing due to high withdrawals than recharge of aquifers by tube wells and other sources of irrigation in rural and urban areas. It results be reduced water availability. This will reduce soil moisture, directly impacting crop productivity and sustainability. It also causes drinking water scarcity for

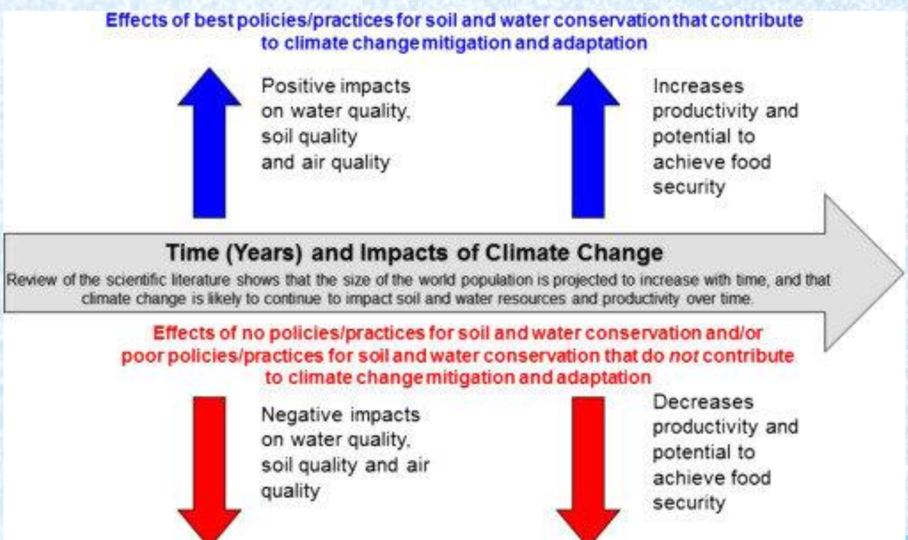

Fig. 1: Relationship between soil and water conservation and climate change

cattle and human being and require migration plan. The rise in sea level is already experienced in the villages of Gujarat and other coastal States.

The Role of Natural Resource Management on Livelihoods

Natural resources are the backbone of human livelihoods, providing food, water, energy, and economic opportunities. Effective resource management ensures the sustainability of these resources and safeguards the well-being of communities that depend on them. This section explores the vital link between resource management and livelihoods, emphasizing the need for inclusive and sustainable practices.

Soil and Water Conservation

Soil and water conservation are central to sustainable natural resource management and hold critical importance due to their role in agriculture, food security, and ecosystem health. Climate change substantially threatens these resources, emphasizing the need for effective conservation strategies. Soil conservation measures such as terracing, cover cropping and reduced tillage help mitigate soil erosion and maintain soil health. On the other hand, water conservation strategies, including rainwater harvesting, efficient irrigation techniques, and watershed management, are essential for preserving this precious resource. Examining real-world examples, sustainable resource management in Costa Rica is notable for its ecosystem-based payments for services, reforestation, and community involvement, showcasing successful practices. Similarly, the Loess Plateau in China demonstrates the effectiveness of massive soil erosion control efforts, grassland restoration and sustainable agricultural practices in soil and water conservation. However, this journey has challenges, including resource governance, effective post management, financing, and balancing local and global interests. Nevertheless, opportunities abound, driven by technological innovations, knowledge sharing, capacity building, and integrating these efforts with climate adaptation and mitigation strategies.

Soil and water conservation initiatives are indispensable in India's quest for resilient livelihoods amid climate change challenges. Healthy soils and abundant water resources are fundamental for agricultural productivity and food security, upon which millions of livelihoods depend. As changing weather patterns bring erratic rainfall and prolonged droughts, India faces increased soil erosion and depleted water sources, putting immense pressure on rural communities. Implementing conservation strategies such as terracing, cover cropping, and reduced tillage is paramount to mitigating soil erosion and maintaining soil health. At the same time, rainwater harvesting, efficient irrigation techniques, and watershed management are essential for preserving precious water resources. India's journey towards universal resource management for livelihood protection amidst climate change underscores the significance of local and global cooperation and emphasizes the need for knowledge sharing and capacity building to empower communities to adapt and thrive in a changing climate.

Soil management

Climate change directly impacts soil, affecting the productivity and sustainability of crops that grow on it. Soil health depends on its capacity to provide the essential services for supporting plant growth and regulating nutrient water, carbon and gaseous cycles. Soil health is widely linked to soil biodiversity. Excess nutrients are released into the soil and used by plants. Sandy soils are the least productive as they do not have the capacity (unlike clay soils and silty soils) to retain moisture and nutrients through chemical attraction (electrical charge). However, sandy soils can be managed productively even in hot, dry climates if there is access to the water, organic materials, and fertilizers required to nourish plant growth. Soil health depends on its capacity to provide the basic services for supporting plant growth and regulating nutrient water, carbon and gaseous cycles.

Soil Moisture Conservation Practices

The objective of soil moisture conservation is to minimize water loss from soils through evaporation, transpiration and evapotranspiration through plants. Methods for reducing soil moisture loss due to direct sun exposure and heat are spreading manure or compost over soil, mulching is a layer of material placed in the root zone of plants such as straw, wood chips, peat, plastic sheeting, conservation tillage, crop rotation of different types of crops to improve soil structure and water holding capacity, green manuring, deep tillage, contour ploughing strip cropping etc.

Farmer management adaptations and use of conservation practices to adapt to a changing climate (e.g., no-till practices, crop rotations, precision conservation, crop selection and dates of planting, harvest, and tillage) have the potential to greatly reduce soil erosion rates (Delgado et al., 2013). Conservation practices will be key and must be used as strategies for adaptation to climate change impacts on the soil resource. Key strategies include the use of conservation tillage, management of crop rotations and crop residue (including use of cover crops where viable), management of livestock grazing intensities, improved management of irrigation systems, use of technologies, and precision conservation. Many other conservation practices also have the potential to reduce much or all of the potential acceleration of soil erosion rates that may occur under a change in climate that will bring more total rainfall with higher intensity rainfall events, or a change to a drier climate that will potentially bring higher wind erosion rates. One important adaptation practice will be to consider projected spatial changes in the hydrological cycle, such as wetter and drier regions, and periods of drought. This could help in the development and/or implementation of soil and water conservation policies that consider the temporal and spatial effects of climate change at the regional level. These policies should also consider conservation practices that contribute to increased water-holding capacity in the soil profile, improved drainage practices, and the development of new crop varieties and cropping systems that are more resistant to drought.

Restoring degraded lands

i. Wetlands

Wetland is an area of land where the soil is permanently saturated with moisture, seasonally or covered by shallow water. Due to climate change, these areas remain inundated for longer period and could be used in many ways. They are useful for food source and resource recycling, the predominant occupation of two-thirds of the working population for their livelihood residing in coastal areas. They could also be used for recreational activities and nature services. In terms of products, they are the source of fish crops, vegetable& rice crops, medicinal plants and other organic products.

ii. Grassland development

Due to continuous heavy rains and floods for a long period due to climate change, there is an acute shortage of fodder and feed to pet animals. Usually, grasslands lack proper management and productivity, which could be improved to meet the fodder requirement at this critical period. In view of this, focus may be on removing unproductive bushes, using suitable fertilizers and manures, introducing suitable legumes and improved cutting and grazing management to supplement the fodder requirement.

iii. Management of ingress of saline seawater

The ingress of seawater due to tidal waves causes nearby areas into saline soils and water. These areas could be managed by preventing the ingress of seawater and intrusion of tidal water in the nearby adjoining low lying areas of sea shore using constructing dyke, pakka wall, embankments, which will restrict the spreading of tidal water in the interior part the sea shore. Planting of trees like bamboo, casuarinas plantations etc, in strip cropping system around the fields to break the wind speed and protect the field with wind erosion. Growing of salt tolerant crops like paddy, wheat, sugar beet, mustard, barley and grasses like Gatton panic, Burmunda grass, Congress grass, Hybrid napier grass and trees like Mangrove, Nilgiri (Eucalyptus), Saru, Subabul, Vilayati babul (Prosopis juliflora), bamboo, etc., can facilitate to improve the physical, chemical and biological rejuvenation properties of the salt affected soils.

iv. Bio-remediation of salt affected soils

Bioremediation is as an economical, sustainable, effective, and climate resilient alternative to conventional remediation technologies. Salt tolerant (Halophilic) microbes are beneficial in alleviating salt stress and also helps in pesticide residue degradation. Bioremediation involves the use of microorganisms or microbial consortiums to reclaim salt-affected soil. These include plant growth promoting rhizobacteria (PGPR), bacteria, mycorrhiza, and cyanobacteria able to reclaim salt-affected soil by producing various hormones and beneficial substances that improve soil quality and plant growth. These microorganisms can enhance plant growth by increasing the supply of growth-limiting nutrients. The application of halophilic bacteria in environmental biotechnology is possible for (1) the recovery of saline soil, (2) the decontamination of saline or alkaline industrial wastewater, and (3) the degradation of toxic compounds in hypersaline environments.

Enhancement of productivity and Income through watershed programmes

Watershed management programmes increase farm productivity and additional income. The analysis of time series data in a 370 ha watershed falling in middle Himalayas during 1974 to 1994 shows remarkable increase in the average yield of all crops from 2.2 to 7.4 times (Samra, 2002). Increased biomass and fodder production resulting from integrated management of watershed at Bunga (Haryana) changed the composition of livestock to more economical animals and reduced seasonal migration of herds due to assured fodder supply. The harvested rainwater in small storage tanks/ structures/farm ponds can be effectively utilized for supplemental irrigation during lean periods to

Table 2: Economic analysis of water harvesting structure

Type of structure	Location	Capacity (ha-m)	BC ratio	Remarks
Unlined pond (natural)	Dehradun (Uttarakhand)	1.65	1.85	Pre-sowing irrigation to wheat
Lined tank	Fakot (Uttarakhand)	-	1.48	Protective irrigation to wheat after terrace improvement
Unlined pond	Sukhomajri (Haryana)	5.5	1.63	Life-saving irrigation to wheat
Unlined pond	Bunga (Haryana)	59.6	3.89	Pre-sowing and flowering stage irrigation to wheat

Table 3: Economic evaluation of watershed management programmes

Watershed	Project span (years)	Discount rate (%)	B:C ratio	IRR (%)
Western Himalayas Fakot, Uttarakhand	25	10	1.92	24
Shivalik hills Rel Majra, Punjab	20	12	1.20	
Sukhomajri, Haryana	25	12	2.06	19
Bunga, Haryana	30	12	2.05	
Joharnpur, Himachal Pradesh	7	10	2.38	28.6

boost crop production. Evaluation of water harvesting in different agro-ecological regions showed that the productivity of arable lands increased by 4.2 to 15.4 q ha^{-1} with benefit: cost ratio varying from 1.48 to 3.89 (Table 2, Samra, 2002). Water harvesting structures have proved to be economically viable, environmentally sound, and socially acceptable. The economic analysis of 21 watershed management programmes conducted in different regions showed that investment in these programmes is a profitable proposition from both economic point of view (Table 3; Samra, 2002).

Conclusion

Soil and water conservation practices are essential component of the watershed development programme. If implemented through farmers' participatory approach, the soil and water conservation practices shall enable the farmers to optimize their crop yields and also rehabilitate the erosion prone degraded sloping lands. The crop diversification and cultivation of high yielding varieties shall be possible if the soil and water resources are properly and effectively managed. Also, the fodder requirements livestock can be locally met. Employment opportunities shall be generated and migration of human population shall be restricted. The overall development and socio-economic upliftment is evident from adopting feasible, easy and effective soil and water conservation measures on watershed basic.

In conclusion, this paper underscores the vital need for a universal approach to natural resource management in the face of escalating global climate change. Climate change threatens both the environment and global livelihoods. Embracing sustainable resource management, particularly focusing on soil and water conservation, is crucial. International collaboration, guided by agreements like the Paris Agreement and Sustainable Development Goals, plays a pivotal role. Governments, NGOs, and local communities must work together, with governments enacting policies, NGOs advocating for sustainable practices, and local communities as immediate stewards of resources. However, universal resource management faces challenges, including political and institutional barriers, equity concerns, balancing local and global interests, and financing complexities. Practical examples, such as India's soil and water conservation efforts, highlight the importance of cooperation, knowledge sharing, and capacity building in empowering communities to adapt to climate change while striving for resilience and sustainability. Universal resource management represents a paradigm shift in addressing global climate change and resource depletion. It champions cooperation, shared responsibility, and sustainability for a more resilient and equitable future for humanity. Despite challenges, the potential rewards are a more sustainable and resilient world.

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WATER RESOURCES MANAGEMENT FOR SUSTAINED DEVELOPMENT AND UTILIZATION IN AGRICULTURE

T.B.S. Rajput

Scientist (Retd), Water Technology Centre, Indian Agricultural Research Institute, New Delhi-110012
tbsraj@yahoo.com

Introduction

Water is the prime requirement for all aspects of life. It is imperative to ensure adequate water supplies of good quality are maintained for all the needs of the entire population while preserving the hydrological and biological functions of ecosystems. Innovative technologies, including improvements in indigenous technologies, are needed to utilize limited water resources fully and to safeguard these resources against pollution. This involves not merely the improvement of engineering parameters e.g., lining of canals/improvement of structures / providing additional field channels, but also application of a complex combination of field disciplines (agronomic / management/field measurement and hydro-sociological aspects) to the irrigated agriculture sector (Patel and Rajput, 2015). This process would also include restoration/rehabilitation / detailed diagnostic analysis and performance evaluation to identify/quantify design and execute the changes required. Development of water resource, its efficient conveyance to all the cultivated fields, and its efficient application at the field and all other activities required to enhance its productivity come under comprehensive water resource utilization in agriculture/ horticulture.

Improving water use efficiency

The overall efficiency in most irrigation systems is low and in the range of 35 percent to 40 percent in surface water systems and 65-70 percent in efficiency in groundwater use. One of the major causes of such poor water use efficiency is the general mismatch between spatial and temporal availability and need of water of growing crops. Being a major consumer of water, even a marginal improvement in the efficiency of water use in the irrigation sector will result in substantial water saving, which can be utilized either for extending irrigated area or diverting the saving to other sectors of water use. Other major issues to be addressed in attempting to improve the efficiencies of irrigation water use include slow progress of irrigation infrastructure under construction, acute need for modernization and rehabilitation of old irrigation systems and irrigation tanks, low reliability in timeliness and equity in irrigation water distribution, major shifts in cropping pattern, unsustained use of groundwater resources, unrealistic pricing of irrigation water and lack of awareness among farmers of the need for efficient use of water (Rao and Rajput, 2006 and 2009). Water application method is also an important area to address for achieving high water use efficiencies.

Due to over draft, substantial groundwater level declines are being witnessed both in hard rocks and alluvial areas. Sea water intrusion due to excessive groundwater development has also affected groundwater quality in coastal areas. Construction of check dams, percolation tanks, recharge wells, subsurface dykes, roof water harvesting and other innovative artificial recharge works and monitoring of the impact of these structures may help overcome the problem.

Ensuring Adequate and Timely Irrigation Water Supply

Disparities in the availability of water between head-reach and tail-end farms and between large and small farms should be obviated by adoption of an appropriate rotational water distribution system. Canal systems need to respond quickly to flow changes. Computer technology is being recognized as a special tool for monitoring and analyzing the data and development of a decision support system (DSS). Special efforts by computer engineers and communication groups have helped establish Management Information System (MIS) for operation of reservoir and canals which helped improve flood control, irrigation and hydropower. In future, from manual operation of canal system, shift to automatic regulation as precise discharge measurements and better communication facilities will be needed. Dynamic estimations of water need of different pockets of the command area nand mechanism to supply required quantities in terms of time and quantity need be attempted to ensure adequate and timely water supply in the entire command area.

Conjunctive use of surface and groundwater

Surface water and groundwater are integral part of available water resources. However, planning for their use has generally been done in isolation, resulting in sub-optimal utilization. For improved water use efficiency in canal irrigated command areas, optimal and efficient utilization of both ground and surface waters becomes imperative. Conjunctive use of surface water and groundwater should be ensured from the planning stage of irrigation projects and should form an essential part of a project. Using surface water during monsoon period and using groundwater during non-monsoon period for irrigation of the same land mass is a form of conjunctive use. Large-scale development of private tube wells in the canal command areas can be viewed as informal practice of conjunctive use of surface and groundwater. In recent times, there is a high emphasis on conjunctive use of canal water and groundwater to exploit the additional potential to augment canal supplies and control the water table rise.

Rational Pricing of Irrigation Water

There is no uniform set of principles for fixing water rates. The water charges vary from State to State, project to project and crop to crop. The rates vary widely for the same crop in the same state depending on irrigation season, type of system etc. The water rates being charged at present are low and are not even able to meet the operation and maintenance costs of the irrigation projects. Water rates being abysmally low, enough funds are not generated for proper maintenance leading to poor quality of service. This is a vicious circle. On the other hand, farmers who otherwise may not be averse to paying increased water charges refuse to do so unless the quality of services is first improved. The tariff structure must be reviewed and revised with simultaneous improvement in the quality of services provided so as to restore efficiencies.

Ensuring Environmental Protection

India's river systems typically originate in its mountain eco-systems, flow towards the plains, and are subject to siltation from sediment loads. They are also subject to significant net water withdrawals along their course, due to agricultural, industrial, and municipal use, pollution from human and animal waste, agricultural runoffs, and industrial effluents. Excessive withdrawals of groundwater in excess of annual recharge, lead to rapidly falling water levels in many areas of the country in recent decades. Rapidly falling groundwater tables are also responsible for continuously decreasing lean season flows in the rivers and streams. Pollution of groundwater occurs due to leaching of stored hazardous wastes, leaching of industrial effluents and use of agricultural chemicals, like fertilizers and pesticides. Appropriate legislation regulation and control are needed to check further degradation of groundwater quality.

Participation of the Stakeholders in Water Management

In order to promote Participatory Irrigation Management (PIM), one-time functional grant is given to the registered Water Users Associations. About 41,200 Water Users Associations covering an area of 8.68 million hectares have so far been formed nationwide. With the formation of Water Users Associations in various projects and the enactment of legislation by various States, more and more irrigation projects are likely to be handed over to these associations for effective management.

Under Restructured Command Area Development Programme more emphasis is being given to participatory approach. In the scheme farmers will have to contribute 10 percent cost of the works in the form of cash/labour involving construction and maintenance of field channels, field drains, reclamation of water-logged areas, desilting and renovation of tanks etc. Such a provision is considered essential to ensure involvement of beneficiary farmers in the construction and maintenance of field channels and imbibe in them a sense of ownership of the assets created.

Adoption of Scientific Water Management Practices

Productivity of irrigated areas in India leaves much to be desired. The productivity in terms of yield per hectare of almost all the crops are way behind the best productivity values achieved elsewhere in the world. In a positive sense, this shows that a great scope exists to achieve higher yields. It is well recognized that a major reason for this situation is unscientific water management practices (Rajput, 1995 and Rajput and Patel, 2005). The measures required include:

A. *Efficient Conveyance and distribution network*

Surface water reservoirs are common in irrigation systems and these are designed and operated to cater to crop water requirement throughout the year. Therefore, It is essential to check water loss in reservoir due to i) Evaporation from the water surface, ii) Seepage from the base and iii) Reduction of storage capacity due to sedimentation. In India, the water loss due to evaporation, seepage, and mismanagement in the conveyance channels (for canals and its distributaries) is exceptionally high, nearly 60%. This loss can be reduced tremendously by taking several measures like lining of water courses, lining not only reduces seepage, but also minimizes weed infestation and reduces overall maintenance cost. The canal network consists of main canals, branch canals, distributaries, water courses and field channels which are termed according to their capacity and orientation with respect to the head-works. In India, the canals and branches up to minor distributaries are generally constructed and operated by the Government. The water courses fall under the jurisdiction of the individual cultivators.

B. *Irrigation Scheduling based on GIS Modeling*

The geographic Information system is used for calculating the crop water requirement before cultivation and helps in scheduling the irrigation need accordingly. Simulation Models are used for respective crops, and each season's water demand is calculated. Also another method used for similar purpose is real time Modeling for irrigation scheduling. The aircraft containing Moisture Sensor along with GPS notes the moisture regime of the farm land and based on this, automated systems are activated.

Historically India had adopted this approach more than a hundred year ago where 370 km long Ganga canal system was operated by British engineers by deploying men at each canal control to operate them such that constant depth is resulted. A humble beginning was proposed in the Bhadra canal system in southern India through a pilot study by CWC and Tungabhadra Board in early nineties. However, this has not yielded any positive results during the canal operation. Operation of Narmada main canal of ambitious Sardar Sarovar Project in the state of The Majalgaon irrigation area, a part of the Jayakwadi scheme (240 000 ha) is one of the largest irrigation areas in Maharashtra which has adopted the concept of canal automation on a pilot basis with the assistance of World Bank.

C. *Water conveyance network*

Design of irrigation water distribution at farm level requires the consideration of three major elements 1. Cross-section, 2. Alignment, and 3. Longitudinal section. Standard procedures are available for determining the cross section of earthen water courses under erodible and non-erodible conditions using Manning's or Chezy's formula. Determination of optimal alignment and Longitudinal sectioning are normally not given the due emphasis. The optimal alignment of water courses in a canal system would provide the minimal total length of water course connecting an outlet to the different fields in its command area. For this purpose the minimal spanning tree model, which is generally applied for laying telephone cables and other similar networks, could be adopted with certain modifications (Rajput, 1991). This model minimizes the total length of connecting different points in space to a given point.

D. *Precision land leveling*

Unevenness in the soil surface adversely affects the uniform water distribution in the fields. Now a day it is possible to do Precision land leveling on the fields, which seems to be leveled with naked eyes, with the help of Laser leveler (Rajput et. Al., 2004).

E. *Measurement of water in the farm*

Flow measurement structures are required in irrigation canals to facilitate water distribution throughout the system and to account for seepage losses, etc. However, in the smaller channels the flow measurement structures or devices are closely associated with local water management practices of an irrigation command.

F. *On-farm options*

1. Use of Water Efficient Crops
2. Choice of irrigation method
3. Choice of cropping pattern
4. Development of land drainage
5. Use of Micro Irrigation

Considerable savings in water can be achieved by adopting sprinkler, drip/micro-sprinkler irrigation systems in water scarcity areas, with conditions conducive to their application. Actual field studies indicated water saving of 25 to 33 per cent and increased yield up to 35 percent with sprinkler system compared with normal surface irrigation method (Patel and Rajput, 2001 and 2012). Further, 10-16 percent more area is available for crops as channels and ridges are not required. As the water is sprayed in the sprinkler method, some evaporation loss occurs. Sprinklers, therefore, should be avoided in zones of high wind. However, this loss of water is eliminated in drip method in which water is directly trickled in to the soil near the root zone of the crop, resulting in considerable savings and is particularly more suitable to row crops. 25 to 60 percent water is saved in drip method and an increased yield up to 60 percent is obtained compared with conventional surface irrigation methods.

Micro-sprinklers are a combination of sprinkler and drip irrigation. Water is sprinkled or sprayed around the root zone of the trees with a small sprinkler which works under low pressure. This unit is fixed in a network of tubing but can be shifted from place to place around the area. Water is given only to the root zone area as in the case of drip irrigation but not to the entire ground surface as done in case of sprinkler irrigation method. This method is very much suited for tree/ orchard crops (Rajput and Patel, 2012).

Conclusion

Water is an essential resource for overall development of human settlements. A densely populated country like India has a large population dependent on agriculture for their livelihood. Over the years, irrigation agriculture has played a significant role in shaping the rural economy and development. However, economy of water usage for agriculture is yet to get adequate attention in the agricultural and irrigation sectors and no concerted attempt was made to deal water comprehensively. PMKSY aims to converge all efforts on water utilization in agriculture into one single scheme, bringing several ministries and departments under one umbrella. Comprehensive district-level planning to develop water resources through watershed development, renovation and upkeep of surface water distribution systems and integration of large irrigation systems with micro irrigation, aimed in the scheme, are likely to achieve the goals of "water to each field" and "per drop more crop".

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WATER MANAGEMENT IN RAINFED AGRICULTURE - NEED FOR A BALANCED STRATEGY FOCUSING ON ECONOMY, ECOLOGY AND EQUITY

Bisweswar Rath

Technical Expert (WM), National Rainfed Area Authority, Department of Agriculture, Cooperation & Farmers Welfare, Ministry of Agriculture & Farmers Welfare, New Delhi

Introduction

Water stands as a fundamental pillar of human survival and ecosystem sustainability. Global apprehensions revolve around the mounting spectre of water scarcity, driven by population growth, developmental imperatives, and their consequential impacts on energy and food production. These concerns gain heightened sensitivity due to the exacerbating ramifications of climate change and human interventions on the delicate balance of natural resources, particularly water. The Global Risk Perception Survey conducted by the World Economic Forum (WEF, 2022) reports that the highest societal impact over the next 10 years will be from the water crisis.

A mounting and unprecedented strain is being placed on water resources across the globe. Rapid population growth compounds this pressure, with projections indicating an alarming 40% deficit between projected demand and available water supply by the year 2030 under prevailing practices. This crisis is further exacerbated by chronic water scarcity, hydrological unpredictability, and the spectre of extreme climatic events like floods and droughts, all of which cast ominous shadows over global food security and overall development. The global population is estimated to touch 9 billion people by 2050, and this will require a 60 percent increase in agricultural production and a 35 percent increase in water withdrawals (INCCA, 2015). Estimates indicate that 40 per cent of the world population live in water scarce areas, and approximately one fourth of world's GDP is exposed to water driven challenges (UNWWAP, 2018). Non- stationary in supply and demand along with water food nexus is expected to enhance the demand of fresh water resources further globally. The intricate interplay of variable water supply and demand and the intricate relationship between water and food production further compounds the exigency of securing adequate freshwater resources on a global scale. This escalating confluence of factors portends a future where the demand for freshwater resources transcends the boundaries of traditional water management paradigms, necessitating innovative and holistic solutions to safeguard the delicate equilibrium of water availability and sustainability.

India's water scenario

India one of the fastest emerging nations, is poised to become a 5 trillion economy by 2025. With an estimated population of 1.42 billion, India has surpassed China as the world's most populous nation (UNDESA, 2023). The increase in population accompanied by rapid industrialization, food production, urbanization and economic development resulting in an improved standard of living is creating huge pressure on water resources both directly and indirectly. India accounts for 18 per cent of the global population and just 4 per cent of the global freshwater resources (NITI AAYOG, 2018). Agriculture is the biggest user of freshwater resources, accounting for over 82 per cent of the available water resources, followed by domestic at 10 per cent and industry at 8 per cent (CGWB, 2014).The dynamics of water availability across the nation's expanse are succinctly captured in Table 1 below

The demand for water for different purposes is increasing due to population growth, urbanization, industrialization, infrastructural needs and quality of life, apart from intensification of agriculture per se. There are two estimates of water requirement for different purposes by the years 2025 and 2050 as shown in the Table 2.

As seen in the table above, there are wide variations between the two estimates, but both show marked increase in the demand in the drinking water, industry and energy sectors.

Table 1: Water availability status (billion cubic meters - BCM)

Annual Precipitation (Including snowfall)	4000
Average Annual Availability	1869
Estimated Utilizable Water Resources	1123
i. Surface Water	690
ii. Ground Water	433

Table 2: Sector-wise demand for water

Sector	Water Demand in BCM			
	Standing sub-committee of MoWR*		NCIWRD**	
	2025	2050	2025	2050
Irrigation	910	1072	611	807
Drinking Water	73	102	62	111
Industry	23	63	67	81
Energy	15	130	33	70
Others	72	80	70	111
Total	1093	1447	843	1180

*Note: *MoWR – Ministry of Water Resources; **NCIWRD – National Commission on Integrated Water Resources Development*

Simultaneously, the estimated demand is also seeing an upward rise in agriculture.

Water Management in Rainfed Agriculture

Current status of rainfed agriculture

Rainfed agriculture is crucial to the country's economy & food security. The small and marginal farmers who account for 80 per cent of the total number farmers are largely inhabitants of rainfed areas. The country's rainfed agriculture accounts for around 40 per cent of the total food grain production, (85, 83, 70 and 65 per cent of nutria-cereals, pulses, oilseeds and cotton, respectively); supports two-thirds of livestock and 40 per cent of the human population. Crop diversity in rainfed regions is salient, with nearly 34 major crops grown annually compared to 4 to 5 major crops in irrigated areas. Rainfed farmers follow a diverse portfolio of economic activities including horticulture, agroforestry, seed spices, medicinal & aromatic plants, fishery, livestock and beekeeping etc. This diversity in the production system imparts greater resilience to the country's rainfed agriculture, and diversifies the consumption plates necessary to address concerns of malnutrition. Rainfed agriculture is practised under various soil types, agro-climates, topography and rainfall conditions. Fragile climatic conditions and experience water scarcity for rainfed crop production characterize India's rainfed regions.

The agricultural productivity of the rainfed regions in India is strongly influenced by the spatial and temporal variability of rainfall. While some of these areas have ground water reserve, the intensive agricultural operations adopted during the green revolution of 1970–1980 have already resulted in declined water tables (Nicholas et al., 2016). In addition, the abnormal variability (both in terms of space and time) in rainfall and temperature associated with changing climate has been a major constraint to crop yield improvements, competitiveness and commercialization of rainfed crop, tree crops and livestock systems in most of the tropical/semi-arid regions (Wani et al., 2009). Evidence shows decreased agricultural production potential in rainfed regions across the country with varying rainfall patterns and volumes due to changing climate (Mandal et al., 2020; Rao, 2013).Therefore, increased food demands, inadequate availability of water coupled with uncertain rainfall (both in terms of amount and duration) warrants sustainable water management strategies in rainfed regions to enhance agricultural productivity and to meet future food security (Surendran et al., 2016; Winter et al., 2017)

Water management in rainfed agriculture- Need for a balanced strategy focusing on economy, ecology and equity

Rainfed areas are characterized by water-scarcity, fragile environments and inadequate institutional credit. The benefit of development of new technologies related to crops, resource management, livestock, and fisheries have not also filtered down amongst farmers in rainfed areas to the extent that has happened amongst farmers in irrigated areas. These unfavourable conditions result in low productivity, low cropping intensity, high cost of production, poor adoption of modern technology, uncertainty in output, and high incidence of rural poverty. The challenge in rainfed areas, therefore, is to improve rural livelihoods through participatory watershed development with focus on integrated farming systems for enhancing income, productivity and livelihood security in a sustainable manner. The watershed approach which has bears the potential for sustainable development of rainfed areas, need to be intensified.

The Government of India has rolled out various schemes/ programmes that aim at improving water availability, mainly through construction of various water conservation structures/ conservation measures in watersheds. Water harvesting structures (such as check dams, farm ponds, percolation tanks etc.), agronomic practices and insitu soil conservation measures, serve to capture the rainwater and check surface runoff to enhance surface storage and recharge groundwater.

The stored-up water in these structures is utilized to meet crop water demands during the soil moisture stress periods. While the current watershed management practices effectively improve water availability, groundwater recharge, agricultural water productivity and their efficiency could be significantly improved by adopting suitable soil and irrigation management strategies and game-changing policy initiatives. Policy recommendations that promote location-specific resource conservation measure are essential in this direction.

Policies and programmes for water management in general and rainfed agriculture in particular should adopt a different paradigm that measures success in terms of inclusive and sustainable growth with regard to system-based alternative output in contrast to season-based productivity. The guiding elements needed are appropriate for efficient natural resource management, income for the farmers, nutritional security and health of the production system. It is important to promote resilience of the diverse production systems, that define rainfed agro-ecosystems and not merely in terms of productivity. The visible policy shift needed in favour of rainfed agriculture is moving away from the present agricultural paradigm of piecemeal interventions to comprehensive treatment for holistically strengthening the agro-ecosystem. The present agricultural paradigm, which subsidizes chemical inputs to maximize yields, was initially designed for the Green Revolution technology, which subsequently came to encompass all crops and livestock. Experience has shown that the current agricultural paradigm has only hastened the degradation of rainfed production systems, leading to diminished returns on investment and inadequate average incomes.

Government of India Initiatives

The Government of India has introduced a comprehensive suite of programs and policies aimed at addressing the multifaceted challenges of agriculture, water resources, and climate change while promoting efficient resource utilization. These initiatives encompass a broad spectrum of strategies, from enhancing agricultural productivity in rainfed regions to optimizing water use efficiency and promoting soil health management, sustainable water conservation, and innovative practices through community engagement. The government's commitment to income-centric agriculture includes supporting farmers' livelihoods through remunerative prices and diversified income sources. Furthermore, the policies target forestry, livestock, fisheries, and marine resources, emphasizing ecological balance and responsible resource management. Within this framework, specific programs like the National Mission on Sustainable Agriculture (NMSA), National Water Mission (NWM), Pradhan Mantri Krishi Sinchaaye Yojna (PMKSY), Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS), Rashtriya Krishi Vikas Yojana (RKVY), Rainfed Area Development (RAD), Mission for Integrated Development of Horticulture (MIDH), and Jal Shakti Abhiyan (JSA), along with other water resource schemes, play vital roles in India's pursuit of sustainable agricultural and water resource management goals.

The Government of India has introduced several polices from time to time, that promote efficient land/water use in the domain of agriculture. Notable policies include the National Policy for Farmers, which focuses on increasing farmers' net income through asset reforms, soil health management, and farmer-friendly insurance. The National Water Policy emphasizes water supply and demand management, incorporating water harvesting and soil conservation techniques. Conservation Agriculture aims to improve soil health through organic farming practices. The New Generation Watershed Development Guidelines, 2020, focus on economic, equity, and ecological principles, with a key focus on treating degraded watersheds and involving people's committees in project implementation. Other policies encompass strategies like doubling farmers' income, fertilizer policy, agricultural price policy, National Food Policy, National Agro-forestry Policy, National Livestock Policy, and National Policy on Marine Fisheries, all designed to enhance agricultural productivity and resource management while ensuring farmers' well-being and ecological balance.

These programmes and policy imperatives collectively epitomize India's systematic and evidence-based approach to engendering resilient and ecologically sound agricultural systems, fostering equitable growth, and safeguarding the intricate balance between resource utilization and environmental conservation.

Proposed Policy Approaches

Promote efficient water resources management in rainfed agriculture

- Improve effective rainfall: As rainfall is the major water source for rainfed regions, 'Effective Rainfall' can harness more rainfall for achieving food security and better livelihoods. Specific technologies that can be integrated within the local context ranging from improving soil organic matter to harvesting and retaining moisture through farm ponds, conservative use etc., combined with a scientific and participatory mapping of resources, water budgeting, mobilization of community to establish usage and extraction norms

- Precision water management practices: Adopting micro-irrigation technologies in rainfed agriculture - which include drip/trickle systems, surface and sub-surface drip tapes, micro-sprinklers, sprayers, micro-jets, spinners, rotors, bubblers, etc., must be prioritized and incentivized through existing schemes/programmes. Studies report that micro irrigation systems deliver water saving up to 40 per cent over conventional flood irrigation, productivity, and income enhancement up to 48 per cent. It also facilitates application of controlled quantities of water and nutrients in the vicinity of each plant.

- Crop diversification for water intensive crops: Studies by NRAA indicate that approximately 6.72% of rice-cultivated land across 68 districts and 12.9% of sugarcane-cultivated land in 91 districts are unsuitable for these crops. Continuing with these crops exacerbates the water supply-demand gap, surpassing available water resources, leading to declining water tables and quality. In response, there is a pressing need for a policy that promotes an agro-ecologically sound cropping pattern, utilizing available water resources efficiently. Shifting from rice and sugarcane to low-water-demand crops like millets, pulses, and oilseeds would benefit numerous small and marginal farmers. Discouraging water-intensive crops in these regions could involve gradually reducing input and energy subsidies and procurement. Additionally, offering crop insurance with higher premiums could deter the cultivation of unsuitable crops.
- Minimizing soil degradation and restoring/ rehabilitating degraded soils: It is important to adopt suitable soil conservation measures based on land capability classes, and landscape planning approach. Soil rehabilitation and/or soil restoration should also be a priority, returning degraded soils to productivity, especially in historically sound agricultural or other production systems currently under threat. Reversing the soil degradation due to low SOC is essential to building back soil carbon, enhancing agronomic productivity, and aiding in sequestering carbon. Improving SOC requires improving water and nutrient use efficiencies by decreasing losses and increasing biomass production. Farming practices like conservation tillage, mulch farming, cover crop, mixed farming/ cropping, agroforestry, ley farming (putting the land under pastures and hay after growing grain crops), utilizing organic manures (vermicompost, green manure) are ways to increase SOC and carbon sequestration. There is significant opportunity to enhance income if farmers are compensated for generating SOC and sequestering carbon.

Technical approaches for enhancing water-use efficiency

i. Some of the key principles for enhancing water use efficiency at field, farm and ecosystem levels for crops grown under rainfed conditions are:

ii. Increase the yield of the crop through varietal improvement, timely intercultural and other on-farm operations, and use of quality inputs;

iii. Potential use of rainwater by adopting in-situ moisture conservation and conservation agriculture practices like timely sowing/transplanting, land levelling, minimum tillage; incorporation of plant residues; and improved drainage for water table control with recycling provisions etc.;

iv. Appropriate alignment of crop / cropping systems, integrated farming system, vertical farming, and mixed farming based on water budget;

v. Use of production technologies like mulching, ridge & furrow method, raised bed & furrow method, farm machineries for plant residue incorporation and minimum tillage, integrated nutrient and pest management, better use of weather forecasts etc.; and

vi. Favourable policy tools for promoting water productivity gains like minimum support price, storage & market facility, value addition, etc. for crops with higher water productivity for specific ecosystems.

ICT approaches for enhanced water use efficiency

Technology adoption in rainfed regions is low and Information Communication Technology (ICT) can be capitalized, as technology adoption rates are higher when ICT and traditional extension systems are blended, compared to dependence on the latter alone. ICT can be leveraged to provide information on several key fronts of water management, including but not limited to:

- Irrigation scheduling, deficit irrigation, precision irrigation, drip irrigation, or improvements in surface irrigation;
- Remote-sensing-based and wireless sensor network-based technologies (WSN) offer popular solutions for irrigation activities. Remote-sensing based irrigation scheduling uses weather information, soil moisture, evapotranspiration, and other ancillary inputs to model crop development and irrigation demand;
- WSN-based technologies can be deployed for on-ground monitoring of agro-hydro-meteorological variables, such as soil moisture, soil nutrients, weather, evaporation, and water level. Soil moisture data helps maintain the soil water between limits - a threshold value (drier value) indicates when to start an irrigation event, and an upper limit (wetter value) indicates the end of an irrigation event; and

- Drones with thermal sensors or satellite imagery, in conjunction with ground measurements, can lead to an improved understanding of crop and water dynamics in a region.
- Communication strategies like irrigation advisories can provide crop water demand and rainfall predictions, customized to the needs of a farmer or irrigation management agency to maximize water-use efficiencies

Improve cropping systems,investment ability, extension and practices

Other than the strategies/approaches for enhancing water use efficiency and natural resources management,the proposed policy goal is to accelerate the growth of rainfed agriculture through a comprehensive holistic approach for combating climate change, securing livelihoods, and improving nutrition.

The policy seeks to maximize gains in ecology, economy, and equity in rainfed areas as mentioned below:

- Improving cropping system practices in rainfed agriculture
  - Release new climate-resilient varieties suitable for rainfed regions
  - Promoting integrated farming & Livelihood systems (IFLS)
  - Improve system productivity in rainfed regions
  - Improve farm power and mechanization in rainfed agriculture
  - Revival of millets based cropping systems
- Enhance investment ability and financial security of farmers
  - Improve access to institutional credit availability for the rainfed farmers
  - Encourage allied agricultural activities in rainfed regions
  - Establishing bio-economy in rainfed regions through promotion of secondary agricultural activities
  - Introduce comprehensive area-yield and weather-based crop- insurance instruments for rainfed farmers
- Improve infrastructure and organization that enhance farmers' capacity to capture value'
- Encourage private sector investments in rainfed regions and sustainable practices
- Improve the knowledge transfer services in rainfed regions
  - strengthen Extension services in rainfed regions
  - leverage the power of ICT in rainfed regions
- Create data monitoring, management and analytics infrastructure for effective decision making
- Provide targeted governance for rainfed regions
  - develop specific ecosystem-based solutions
  - introduce targeted schemes for vulnerable and disadvantaged group

Regulatory Acts/ Reforms

Land ownership and farm productivity are interlinked:The connection between land ownership and farm productivity is crucial in India. Many urban individuals and professionals who are not full-time farmers own a significant portion of agricultural land. This non-involvement in farming negatively impacts productivity and sustainability. Land is often viewed as an inherited asset from non-agricultural backgrounds. Since land leasing is mostly illegal, a substantial amount of land remains unused, and when it is informally leased, lessees often disregard ecological and sustainable farming practices.

Moreover, these lessees are ineligible for government and institutional support, leading to suboptimal productivity. Legalizing land leasing, as per the Model Land Lease Act of 2016 by NITI Aayog, is necessary to address this. Additionally, as recommended by the DFI Committee, the definition of a farmer should not depend on land ownership, and government and institutional support should be based on actual cultivation during the current season, requiring the maintenance of a digitally enabled dynamic farmer database.

Judicious use of the groundwater is a critical intervention needed for sustainable rainfed agriculture. Groundwater governance entails the focus of political, social, economic, and administrative systems. Water governance in India being a state subject, legislations in state legislative assembly on groundwater will be a critical catalyst in the success of rainfed agriculture programs. Studies show a rapid decline in usable groundwater between 2005 and 2019 in the States of Punjab, Rajasthan, Maharashtra and Telangana leading to the risk of severe food crisis and drinking water scarcity for rainfed regions of the country. Limiting subsidized electricity and adoption of a mechanism of pricing for groundwater usage will be a critical reform in the domain of conjunctive use of groundwater for rainfed agriculture.

Dedicated water-related Policies/advisories for rainfed areas: Rainfed areas need a differentiated focus on water management (policy, investment, technology, institutions) based on a framework of dedicated water-related policies.

Currently, the national water policy for the agriculture sector is mostly oriented towards irrigation. Gauging and volumetric measurements of micro-watersheds at the outlets of catchments is necessary to assess the water use at micro-watershed scale and suggest management approaches. Water Foot Print demarcation for rainfed agriculture products offers an objective indicator to quantify the water utilization volume per harvest unit. Region-specific water foot print quantification of rainfed agriculture crops is to be standardized with specific Guidelines. Water foot printing will be a critical developing strategy to study about water consumption and distribution in the rainfed regions.

Supportive policies towards crop diversification: Interlinking of crop diversification and policies/programmes is essential for dissuading farmers from growing water-intensive crops. According to the studies, sizeable extent of paddy and sugar cane cultivation is practised in regions that are incompatible with available water resources. It is necessary to adopt a policy that disincentivizes cultivation of agro-ecologically non-suitable crops and is incentivizes of agro-ecologically suitable crops.

Designing institutional mechanisms that enhance water productivity: Water management in agriculture comprises different actors who are required to interact and cooperate for a system to work effectively on a variety of scales: river basin, watershed, hydrologic unit, and at the farmlevel. Therefore, structuring a water management sector should not only be a set of effective organizations but also possess adequate governance mechanisms for better operational capacity among them. Three institutional levels can be envisaged viz.,: (i) Water Management Boards at the headwork and main canal level and (ii) Distributary Stations (DS) at the secondary canal level; and (iii) Water User Associations (WUA) at the tertiary and farm canal level.

Political will, leadership and *cooperative federal governance*: Political will and engagement of political parties is a significant driver in achieving developmental goals and preparing the people to accept reforms relating to water use efficiency. There is a need that political leadership establishes a clear vision of large-scale change in water governance and water user efficiency, being as they are foundational to that of transformation. Active personal engagement at the governance level helps accelerate programme success.

Behavioural experiments, customized local strategies and participatory stakeholder engagement: It is imperative to undertake a detailed study in the country's agro-ecological regions to understand the impact of technologies, pricing and other economic policies on water productivity. This could also take the form of behavioural experiments that provide evidence for more informed interventions, that could act as pilot projects. Devising local-specific customized strategies based on existing institutions and enabling participatory stakeholder engagement are crucial steps for enhancing water productivity. In the context of the country, each state would prefer a mechanism that best fits its unique needs, though some dimensions of institutional mechanisms could be similar across states.

Conclusion

Agriculture's economic viability hinges on water availability, making the repercussions of climate change, water scarcity, and poor natural resource management felt across ecosystems and support systems. It is essential to appreciate the organic linkages across various domains. Hence, new approach based on the triple principles of economy, equity and ecology is the need of the hour. In this intervention matrix, water and air are the most critical elements that demand priority attention in the context of increased water demands and climate change, enhanced livelihoods, and nutritional security. These approaches offer a pathway towards resilient and productive rainfed ecosystems by promoting efficient water resource management, minimizing soil degradation, adopting technical innovations, strengthening institutional mechanisms, and engaging stakeholders.

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SOIL CONSERVATION SOCIETY OF INDIA- AT A GLANCE

BACKGROUND

Soil Conservation Society of India was established at Hazaribagh, Bihar (now in Jharkhand) in December 1951, at the first National Symposium on Soil Conservation organized by the first multidisciplinary Department of Soil Conservation created by the Damodar Valley Corporation, on the pattern of the Tennessee Valley Authority (USA). The society was registered at Patna, Bihar vide No. 14/1952-53 under the Societies Registration Act of 1860.

OBJECTIVES

- Survey and assessment of natural resources of the country in a systematic manner using modern techniques of remote sensing, computerized interpretation for conservation and development programmes.
- Promote technical and latest advanced knowledge of soil and water conservation livestock, Micro flora, Frow Forest and management practices for land degradation, rainwater harvesting, runoff and control peak of water for all sustainable agriculture production systems. (including Bio-industrial Watershed Management).
- Promotion and implementation of integrated watershed management approach through the people's and Government involvement.
- Coordination and implementation of all matters relating to soil and water conservation and Management with reference to ecology and biodiversity among the various agencies—viz government and non-government organization in order to facilitate policies of the Central State Government for Food Security and Agricultural sustainability.
- Development and management of micro water resources as a vital pre-requisite of bioproduction, forestry, animal husbandry and fisheries, land management, rural development, environmental protection and other bioresources uses and conservation programmes within watersheds.
- Developing programmes of ecology, agriculture, for enhancing sustainability for rural development livelihoods to improve incomes through integrated farming system and bioindustrial watershed approach, processing agricultural produce, value addition, Market networking in the watersheds.
- Judicious and Scientific proper soil and water conservation, development and management in the irrigated and rainfed area.
- Development of Soil and Water Conservation in the rainfed areas for enhancing land productivity and harnessing rainwater.

ACTION & ACHIEVEMENTS

Publications

The Society has also brought out a number of publications based upon the papers presented in its National and International Seminars and Conferences. Besides, the society has published more than 20 books on watershed development, conservation farming, wasteland development and other related topics on soil and water conservation.

Journal

Society brings out quarterly Journal of Soil & Water Conservation and quarterly Newsletter Soil & Water Conservation Today. The research papers are received from the experts, scientist, researchers and students are published in this journal which are duly scrutinized and recommended by the referee on different topic and different suitable topic which are consider in this journals.

Library

The Society maintains a library which has more than 2500 books technical on various subjects relating to the Natural Resources, Conservation, Development, Management, Success Stories, bulletin, journals, pamphlets, proceeding of various conferences and other miscellaneous literature.

Seminar, Conference, Workshop

The SCSI has been organizing National and International Conferences, seminars and workshopsat various places of the country. Till date, the society has organized 31 National, 4 International Conferences and 2 Asian Congress successfully and 5th International Conference is being organized in November 7-10, 2023 at New Delhi on various subjects.

Members

The membership of the Society is open to individuals, institutions and organizations serving for welfare of the farming community and conservation of natural resources. The society is having at present 3250 life and annual members, 50 institutional members and more than 500 student members.

State Chapters

The Society extended its activities by establishing state Chapters in various parts of the country. Currently, 23 state Chapters of the SCSI are functioning namely (1) Andhra Pradesh (2) Arunachal Pradesh (3) Assam (4) Bihar (5) Rajasthan (6) Chhattisgarh (7) Gujarat (8) Jammu & Kashmir (9) Karnataka (10) Kerala (11) Madhya Pradesh (12) Maharashtra (13) Meghalaya (14) Mizoram (15) Nagaland (16) Orissa (17) Punjab (18) Tamil Nadu (19) Telangana (20) Tripura (21) Uttrakhand. (22) Uttar Pradesh (23) West Bengal (24) Sikkim.

Memorial Lecture

The Society has been organizing the memorial lectures to commemorate the founder member, eminent soil scientist and Soil Conservationist in India so far Dr. Y.P. Bali and Prof. J. S. Bali Memorial lectures have been organized.

Awards

In order to encourage the talent in all fields of research and development engage for the cause of conservation and management of the land, water and other natural resources, the Society honouring them by giving awards. The awards instituted by the Society to recognize dedicated services of the professionals and scientists by conferring them with various awards.

List of Awards

(i) Classified Awards

A. Bhu Ratna Award Bi-Annual

B. Life Time Achievement Award

C. National Fellow Award

D. Gold Medal Award

E. Leadership Award

F. Student Incentive Award

G. Communication Book Award

H. Special Research Award

(ii) Unclassified Awards

A. Special Honour

B. Honorary Membership Award

C. Sponsored Awards

Website

The dynamic website of the society has been created, which is http://scsi.org.in and is functioning well.

LIST OF AWARDEES FOR THE 2022

1. Life Time Achievement	Dr. S.K. Dubey	
2. National Fellow	Dr. P K Shrivastava	
	Dr. Munish Kumar	
	Er. RAS Patel	
3. Gold Medal	Dr. Manmohanjit Singh	
	Dr. Raj Kumar Singh	

	Dr. Anchal Dass	
	Dr. D.V. Singh	
4. Leadership Award	Dr. Sanjeev Kumar Gupta	
	Dr. Partha Pratim Adhikary	
	Dr. P.P. Dabral	
	Dr. Rajendra Singh Negi	
5. Special Research Award	Dr. Sanjeev Panwar	

	Dr. Geeta Kumari	
	Dr. V. Kasthuri Thilagam	
	Dr K Rajalekshmi	
6. Dr J.S. Bali Award	Dr. R. Srinivasan	
7. Sumer Memorial Award	Dr. S.M. Vanitha	
	Dr. R. B. Sinha	
8. Student Incentive Award (PhD)	Dr. Ajeet Kumar	

9. Student Incentive Award (MSc)	Miss Ventina Yumnam	
	Mr. Gangannagari Karthik Reddy	
10. Mrs Mohini Kumari Gupta Memorial Merit Scholarship	Ms Tamanna Sharma	
11. Best State Chapter-2022	Meghalaya State Chapter of SCSI	

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5th International Conference on Sustainable Natural Resource Management under Global Climate Change November 7-10, 2023

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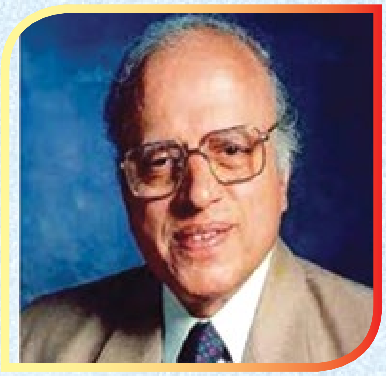


Prof. M.S. Swaminathan
Chief Patron
SCSI, New Delhi

It is with profound sorrow that the Soil Conservation Society of India (SCSI), announce the passing of our beloved Chief Patron, Prof. M.S. Swaminathan, on 28 September 2023, at the age of 98. He was born in Kumbakonam, Madras Presidency, on 7 August 1925. His departure leaves a void that will be deeply felt by all who were touched by his wisdom and dedication. Prof. Swaminathan, a true luminary in agriculture, leaves a legacy that will continue to inspire generations. Prof. M.S. Swaminathan's contributions to agriculture were nothing short of extraordinary. His pioneering work in agricultural research and development played a pivotal role in alleviating hunger and enhancing food security globally. His unwavering commitment to sustainable farming practices, crop diversification, and the empowerment of small-scale farmers has profoundly impacted food production and rural livelihoods.

He dedicated his life to ensuring that the benefits of scientific advancements in agriculture reached all the farmers. His tireless efforts in developing high-yielding crop varieties, advocating for environmentally responsible farming techniques, and championing food security as a fundamental human right earned him the title of the father of the Green Revolution of India.He headed the Indian Council of Agricultural Research (ICAR) and served as the Director General of the International Rice Research Institute, Philippines. He was awarded the first World Food Prize in 1987 and conferred the Padma Shri, Padma Bhushan and Padma Vibhushan for his outstanding contributions. He also received several other awards like the Shanti Swarup Bhatnagar Award, Lal Bahadur Shastri National Award and the Indira Gandhi Prize.

We were fortunate to have him as Chief Guest of the National Conference of SCSI organized at Lucknow (UP) in 2013, making the event memorable. His blessings and encouraging messages for our activities showed his affection and support for the organization.As we grieve the loss of this visionary agricultural scientist, let us also celebrate his enduring legacy. Prof. M.S. Swaminathan's life's work serves as a beacon of hope and inspiration for all those committed to addressing the challenges of feeding a growing global population while preserving our planet's precious resources.

OBITUARY

Dr. Suraj Bhan
President
SCSI, New Delhi

We deeply mourn the loss of Dr. Suraj Bhan, a prominent figure in agriculture and soil science and President of the Soil Conservation Society of India from 2005 to 2023. He was born on 15th July, 1945, in Sikehara, Etah. He dedicated his life to the pursuit of knowledge and excellence. Dr. Bhan passed away on October 15, 2023, leaving a legacy of profound contributions. His academic journey was marked by exceptional achievements, including a Ph.D. in Soil Science from the renowned Indian Agricultural Research Institute. With 47 years of experience, he specialized in Soil Fertility and productivity, Soil and Water Conservation. Hecontributed significantly to the scientific community, including over 205 research papers/technical papers, reviews, case studies, popular articles, technical bulletins, and 10 technical books on various topics.

Dr. Bhan's outstanding leadership earned him awards such as the SCSI-Bhu Ratana Award in 2014, Life Time Achievement Award (2009), National Fellowship Award (2006), SCSI Book Award (2006), Gold Medal Award (2003), International Human Rights Award by All India Human Rights Association, New Delhi (2002), Leadership Award (1993), in the area of Global Warming Reduction and Climate Change Management by Global Warming Reduction Centre, New Delhi. He was a life member of numerous prestigious societies, reflecting his commitment to his field. Dr. Suraj Bhan's legacy will continue to inspire future generations. His family, friends, colleagues, and the scientific community will deeply miss him.

May his soul rest in peace.

National Academy of Agricultural Sciences

New Delhi, India

The Academy

The National Academy of Agricultural Sciences (NAAS), established on June 5, 1990, continues to be a unique think tank and an important forum for harnessing science for enhancing productivity, profitability, equity and sustainability of Indian agriculture. The Academy has emerged as a vibrant national agricultural science organization devoted to promoting agricultural research, education, knowledge pool, national and international partnerships and science-society interface towards transforming agriculture and food policies leading to a food-nutrition-livelihood-ecology-secured and climate-smart India.

Academy Headquarters at the National Agricultural Science Centre Complex, Pusa, New Delhi

Mission

To promote excellence in science, act as a credible think tank of the scientific community and provide science-based inputs for policy options for a vibrant agriculture.

Objectives

The major objectives of the Academy, *inter-alia*, are to:

- To promote ecologically sustainable, economically viable and environment friendly agriculture,
- To recognize and support excellence of scientists, teachers, industry individuals, farmers and media personnel in agriculture,
- To promote interactions among the researchers in different national and international organizations,
- To secure and manage funds and endowments for the promotion of agricultural sciences
- To publish journals, policy papers, and other documents for the advancement of agricultural research, education and development
- To conduct other activities relevant to the accomplishment of the above goals, in public interest
- To organize inter-disciplinary events on issues of importance to farmers and farming, and provide evidence-based inputs for policies to advance agricultural research, education, strategic knowledge pool, and extension for development

Governance

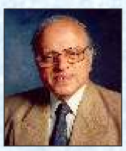
The governance of the Academy is through (a) General Body, (b) Executive Council, (c) Statutory Committees, and (d) Regional Chapters. General Body is the supreme authority comprising of the entire Fellowship and meets once a

A view of the meeting of the Executive Council in progress

year. During this meet, newly elected Fellows are inducted, and major policy decisions are discussed. The Executive Council is the main policy, decision making and implementing body, and it meets four to six times a year. Executive Council comprises of the President, Immediate Past President, two Vice Presidents, two Secretaries, Foreign Secretary, Treasurer, two Editors, twelve Members and one ICAR Nominee. The Academy has a few Statutory Committees to deal with various aspects of its governance. Presently, it has 12 Regional Chapters functioning at Barapani, Bengaluru, Bhopal, Cuttack, Coimbatore, Hyderabad, Karnal, Kolkata, Lucknow, Ludhiana, Pune, and Varanasi. In line with the objectives of the Academy, the activities of the Chapters include organizing workshops, brainstorming sessions and lectures on topical issues; undertaking public awareness exercises for the popularization of science and issues of national/state interests; publishing periodicals, newsletters and directories of agricultural scientists; undertaking schemes for recognizing and motivating young scientists; and consultancies.

NAAS Presidents

World-renowned academicians have been the Presidents of the Academy, who eminently guided its destiny over years and through their vision and wisdom helped accelerate the pace of growth of the Academy.



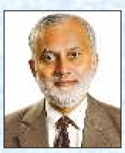
Prof M.S. Swaminathan
1992 - 1996
2005 - 2007

Dr R.S. Paroda
1997 - 2000

Prof V.L. Chopra
2001 - 2004

Dr Mangala Rai
2008 - 2010

Prof R.B. Singh
2011 - 2013



Dr S. Ayyappan
2014 - 2016

Prof Panjab Singh
2017 - 2019

Dr T. Mohapatra
2020 - 2022

Dr H. Pathak
2023 - till date

Fellowship

To recognize academic excellence, the Academy elects 29 Fellows every year in the following eight scientific sections. The section-wise distribution of the Fellowship is indicated in parenthesis.

1. **Crop Sciences:** Genetics and Plant Breeding, Plant Genetic Resources, Plant Biotechnology, Plant Physiology & Biochemistry, Seed Technology and Post-Harvest Technologies for all field crops (6).
2. **Horticultural Sciences:** Genetics and Plant Breeding, Plant Genetic Resources, Plant Biotechnology, Plant Physiology & Biochemistry, Seed Technology and Post-Harvest Technologies for all horticultural crops (3).
3. **Animal Sciences:** Animal Genetics & Breeding, Animal Nutrition, Animal Physiology, Animal Biochemistry and Biotechnology, Animal Production, Animal Reproduction, Animal Health, Animal Products Technology, Dairy Sciences and Poultry Sciences (4).
4. **Fisheries Sciences:** Fish Genetics & Breeding, Fish Nutrition, Fish Pathology, Fish Biotechnology, Fish Biosystematics, Fish Processing & Technology, Fisheries Resource Management and Aquaculture (2).
5. **Natural Resource Management Sciences:** Agricultural Meteorology, Agronomy, Environmental Science, Forestry, Agroforestry, Soil Science including Soil Microbiology, Water Management (excluding Soil and Water Engineering) and Agricultural Physics (5).
6. **Plant Protection Sciences:** Agricultural Chemicals, Agricultural Entomology, Plant Pathology and Nematology, Organic Chemistry, Microbiology in relation to Plant Protection (4).
7. **Agricultural Engineering and Technology:** Farm Machinery & Power, Soil and Water Engineering, Agricultural Process Engineering, Value addition and Post-Harvest Technology, Food Technology, Textile Technology and Computer Application in Agriculture (2).
8. **Social Sciences:** Agricultural Economics, Agricultural Statistics, Extension Education, Bioinformatics, and Community Science, including Food Science and Nutrition (3).

Dr W.D. Dar, receiving Fellowship of the Academy

Foreign Fellow (2): The Academy also elects two Fellows who are foreign citizens; eminent and internationally recognized leaders in their areas of specialization; have made notable scientific contributions with wider implications for global agriculture including Indian agriculture.

Dr Jose Graziano da Silva, DG, FAO receiving the Foreign Fellowship

Pravasi Fellow (3): The Academy elects three Pravasi Fellows who are the Persons of Indian Origin (PIO) or Overseas Citizens of India (OCI), holding foreign passport (residing within or outside India), eminent for their knowledge and contributions to agricultural sciences, and have contributed to the progress of agricultural sciences in India, or persons holding Indian passport (residing outside India) and having done their work in foreign or international organizations.

The total fellowship of the Academy, as of 1.1.2023 was 758, which includes 57 Foreign Fellows and 17 Pravasi Fellows.

Associateship

The Academy inducts scientists below the age of 40 years as Associates of the Academy based on their scientific contributions. So far, the Academy has selected 160 scientists as NAAS Associates, of which 46 Associates have over time been elected as Fellows of the Academy.

Young Scientist Awards

The Academy has instituted the Young Scientist Award in 1998 for recognizing excellence in research in Agricultural and Allied Sciences, including Environment and Nutrition for the scientists below the age of 35 years. Eight scientists are selected for the Young Scientist Award in recognition of their contributions in their respective disciplines every year. Till now, 65 scientists have been conferred with this award.

Corporate Fellowship

The Academy recognizes the role of private organizations in promoting agricultural research and development. It encourages the business houses and corporate bodies connected with agriculture to become Corporate Fellows by contributing at least Rs. 10 million to the Corpus Fund of the Academy or for its activities needing sustained long-term funding support. The Academy can institute an award in the name of the corporate house, the funding for which is done from the interest accrued on the donated amount. Presently, the Academy has one Corporate Fellow.

Corporate Membership

A corporate body, having established reputation and willing to contribute Rs. 2.5 million or more towards the Corpus Fund of the Academy or for its activities needing sustained long-term support, demonstrably involved or proposes to be involved itself in the activities related to the objectives of the Academy or should be in conformity with the requirements of preserving human, ecological and environmental health, is eligible for Corporate Membership of the Academy.

Institutional Membership

Any national/international academic organization, having established reputation, demonstrably involved or proposes to be involved itself in the activities related to the objectives of the Academy or should be in conformity with the requirements of preserving human, ecological and environmental health, and willing to pay Rs. 1 million towards the NAAS Corpus Fund for supporting its long-term activities, is eligible for Institutional Membership of the Academy. The number of Institutional Membership currently stands at 37.

The Corporate Fellows / Members and Institutional Members can avail the opportunity to participate in scientific activities organized by the Academy; propose activities to be organized by the Academy in mutually agreed areas consistent with the Academy's objectives, be given a set of publications of the Academy free of cost, and attend the Annual General Body Meeting of the Academy as observers, but will not use the name of Academy for any commercial or promotional activity of their products.

Awards

The Academy has instituted various categories of awards to recognize and encourage meritorious and distinguished scientists for their celebrated contributions to the cause of agricultural research, education and extension. These awards consisting of scroll/silver plaque/citation/gold plated silver medal/cash, are given once in two years during the Agricultural Science Congress. The awards are as follows:

- Six Memorial Awards
- Six Recognition Awards
- Dr A.B. Joshi Memorial Lecture Award
- Three Endowment Awards (Shri L.C. Sikka Endowment Award; Dr (Ms) Prem Dureja Endowment Award; Dr N.G.P. Rao Endowment Award)

Congresses, Conferences, Workshops and Brainstorming Sessions

The Academy biennially organizes the National Agricultural Science Congress to provide a vibrant platform to leading experts, practitioners and stakeholders in agriculture and related sectors to discuss and exchange views on contemporary issues in Indian agriculture and for priority actions on transforming Indian agriculture and food systems. So far, 15 Agricultural Science Congresses have been organized. The theme of XV Congress was "Energy and Agriculture: Challenges in 21st Century".

Inauguration of the First Agricultural Science Congress at New Delhi on November 12th, 1992

Inauguration of the XV Agricultural Science Congress at BHU, Varanasi on November 13th, 2021

During the year of the Congress, the Academy conducts an Elocution contest, generally on the Congress theme, involving students from Agricultural Universities and ICAR Deemed Universities, and awards the national level winners during the Congress. On this occasion, an Agri-Expo is also held. Another important feature of these Congresses is the Farmers – Scientists interaction where a large number of farmers raise many issues concerning their farming practices in view of the changing environment and the experts present satisfactorily explain to them the coping strategies that farmers need to adopt to minimize production loss.

Bharat Ratna H.E. President of India Dr. A.P.J. Abdul Kalam inaugurating the Academy's National Symposium on 'Agriculture Cannot Wait: New Horizons' on 05 June 2007

The Academy conducts International and National Conferences, Symposia, Workshops, Seminars and Brainstorming Sessions. The Academy organized a National Symposium on "Agriculture Cannot Wait: New Horizons" to commemorate 60 Years of India's Independence. On this occasion, Bharat Ratna H.E. President of India, Dr A.P.J. Abdul Kalam delivered a Special Lecture on "Innovate to Empower Agriculture". The President highlighted the attention of the scientists to farmers' actual problems, which need unique solutions in future.

More than 100 Brainstorming Sessions on contemporary issues, and 3 International Congresses have been organized so far. The Academy also organizes lectures by eminent scientists from India and abroad.

Silver Jubilee of the Academy

The Academy celebrated the Silver Jubilee of its foundation in 2015. A panel discussion on 25 years of achievements in agricultural sciences and the way forward for 2030 was held under the chairmanship of Prof M.S. Swaminathan. The Foundation Day Lecture on "Structure of Indian Agriculture – Growth and Policy Epochs" was delivered by Prof Y.K. Alagh, former Union Minister of Government of India.

Silver Jubilee Celebrations of NAAS

Golden Jubilee of Green Revolution

The Academy in collaboration with the ICAR and IARI organized a one-day scientific discourse on November 27, 2015, to commemorate the Golden Jubilee of India's Green Revolution that transformed agriculture towards self-sufficiency, surpluses and exports with the team efforts of technologists, farmers, policymakers and more importantly the political will. Prof M.S. Swaminathan, eminent scientists, farmers and institutions were also felicitated. Sessions like "As They Saw It - Impressions" and "Path Ahead" were organized and several presentations were made by the scientific experts.

Glimpses of Golden Jubilee of Green Revolution

Publications

The publications of the Academy include (a) NAAS Newsletter, (b) Policy Papers, (c) Status/ Strategy Papers, (d) Policy Briefs, (e) Study Reports, (f) Annual Reports, (g) Foundation Day Lectures, (h) Presidential Addresses, (i) Journal - Agricultural Research, (j) Books, and (k) Year Book. As of now, the Academy has published 121 Policy Papers, 18 Status/Strategy Papers, 13 Policy Briefs, 13 Proceedings on important issues pertaining to agriculture, besides the Abstracts and Proceedings of Agricultural Science Congresses. "Hundred Years of Agricultural Sciences in India" is the most celebrated book of the Academy, which has been received, appreciated and read globally. Its contents depict the heritage of Indian agriculture and the research contributions towards agricultural sciences are the epitome of its journey and directions of research over the last 100 years towards self-sufficiency, food for all and bringing a smile to the farmers.

In order to disseminate and promote research in newer and emerging areas of agricultural sciences globally, the Academy launched an International Research Journal 'Agricultural Research' in 2012 in collaboration with Springer India Pvt. Ltd. Four issues of the journal are published each year. Till now 12 volumes have been published. The Academy has brought out so far 23 NAAS Newsletters (4 issues per volume) flagging the latest issues, trends and discoveries, and it also publishes Year Book (a compilation of profiles of the Fellows and guidelines of the Academy) and a Year Planner every year.

Initiatives for Promoting Excellence in Science

The Academy has gained recognition as a credible think tank to provide views of the scientific community on issues related to research, education, extension and policy for agricultural development. It promotes excellence in science to make it a powerful instrument for a sustainable and vibrant agricultural sector. It has launched schemes for Mentoring of the young scientists; Reaching the farmers; Lecture series by NAAS Fellowship in the Universities; Formulating science communication strategy; Agropedia enrichment; Short-term studies on topical issues; Profiling of institutions and scientists in NARES; Impact Assessment, Monitoring and Evaluation; Consultancy Services and Agri-preneurship Development, and Agri-Road shows at the Agricultural Universities.

- The Academy has also initiated interactions with the agro-industry sector and the first "Academia-Industry meet on Policy Issues in Agriculture and Allied Sectors" was organized in December 2022. It was followed by the "Investors Meet" in August 2023.
- From 2023, the National Academy of Agricultural Sciences, New Delhi has initiated a one-week Pedagogy Development Programme (PDP) training on "Enhancing Pedagogical Competencies for Agricultural Education". The first event was organized during July 31 to August 5, 2023 at NAAS, New Delhi.

The Academy also periodically rates Indian Scientific Journals related to agriculture and allied sciences, which provides guidance to publishers for improving their quality.

National and International Linkages

The signing of MoU with the Italian Academy

To address issues concerning the better public understanding of science and identifying the frontline issues in which science and scientists have a stake, the Academy has developed linkages with ICAR Institutes, Agricultural Universities and other Research Organizations and NGOs. It works closely with the other Science Academies of the country including the Indian National Science Academy; Indian Academy of Sciences; Indian National Academy of Engineering; National Academy of Sciences, India; National Academy of Medical Sciences; and National Academy of Veterinary Sciences.

The Academy has established linkages with Science Academies in other countries as well. Twelve Memoranda of Understanding have been signed with Science Academies abroad. It played a key role in the establishment of the Afghanistan Academy of Agricultural Sciences.

Infrastructure

The Academy has developed excellent modern conference facilities which can be availed on nominal payment. It also has a library with a good collection of journals and books. The dedicated staff of the Academy's secretariat helps in the efficient and timely organization of all its activities.

Contact

Executive Director

National Academy of Agricultural Sciences

NASC, Dev Prakash Shastry Marg, Pusa, New Delhi 110 012

Ph.: +91 11 2584 6051, 2584 6052, Fax: 2584 6054

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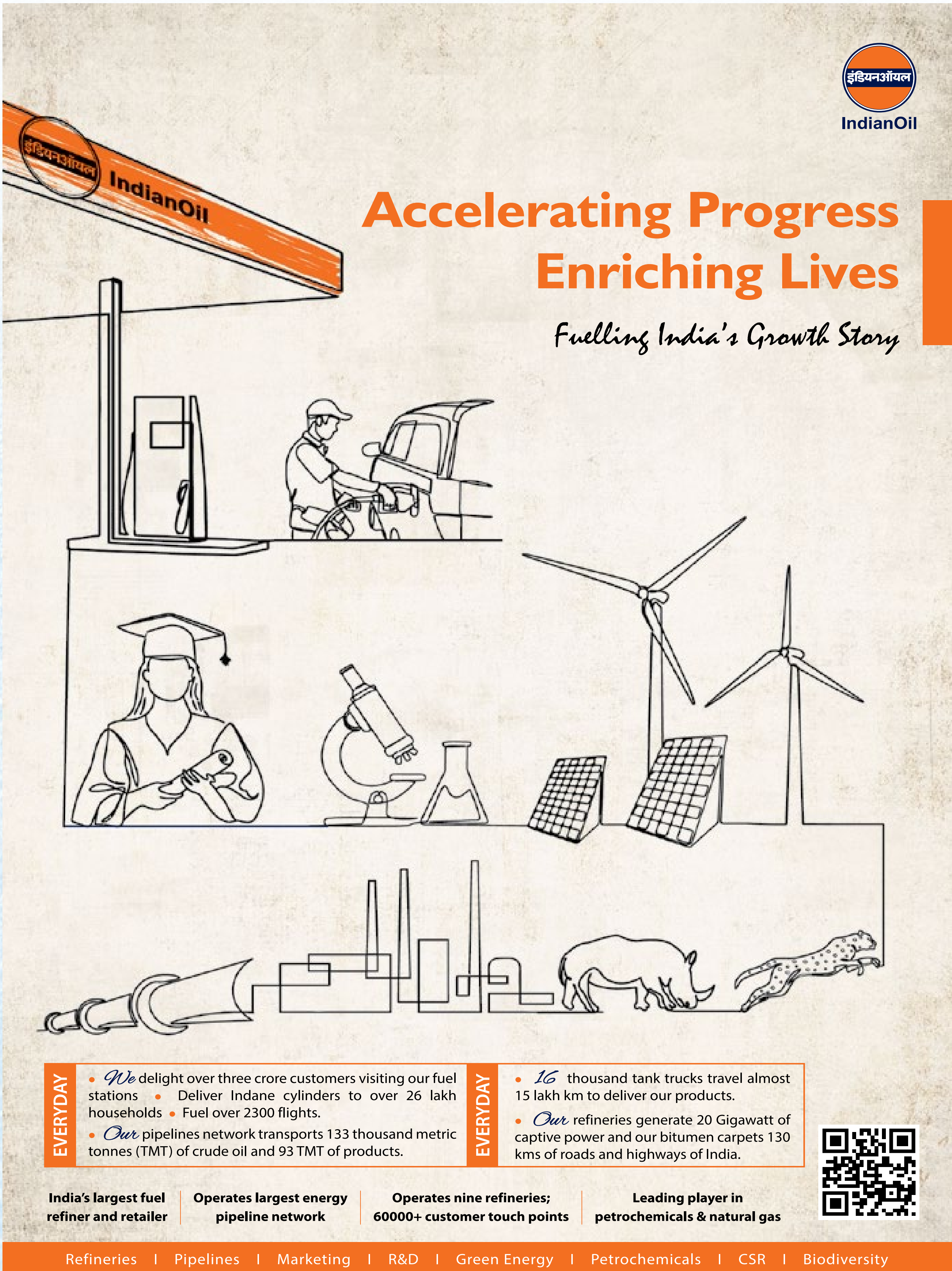
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EVERYDAY
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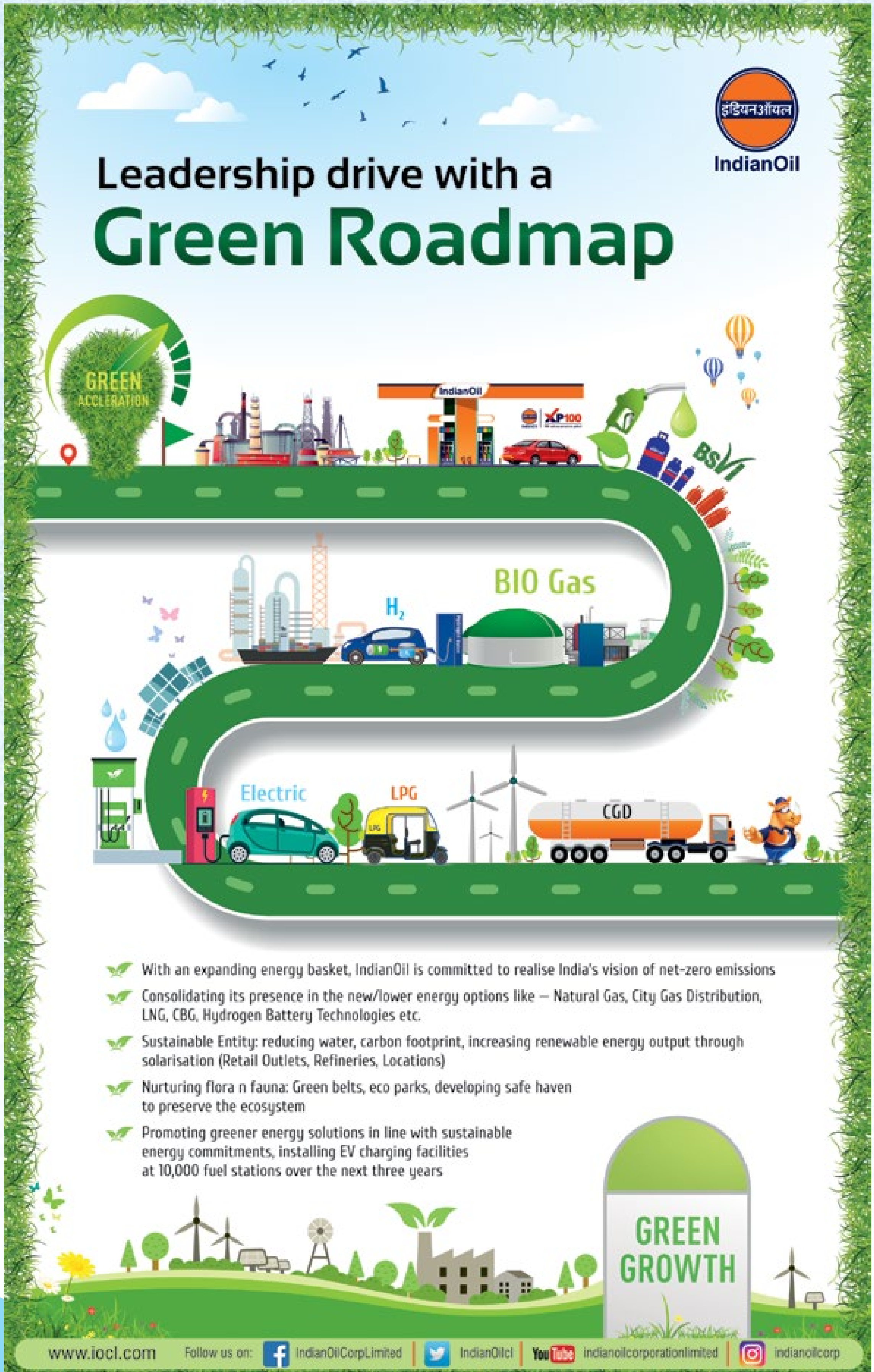
• Our refineries generate 20 Gigawatt of captive power and our bitumen carpets 130 kms of roads and highways of India.
India's largest fuel refiner and retailer
Operates largest energy pipeline network
Operates nine refineries; 60000+ customer touch points
Leading player in petrochemicals & natural gas
Refineries I Pipelines I Marketing I R&D I Green Energy I Petrochemicals I CSR I Biodiversity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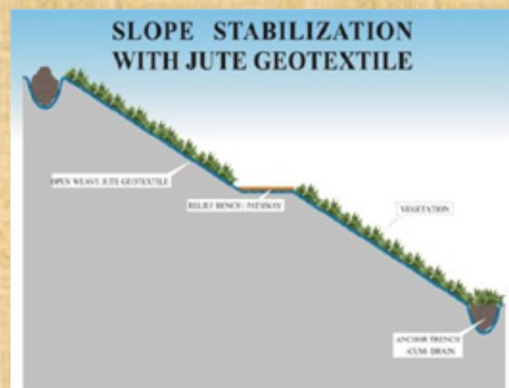
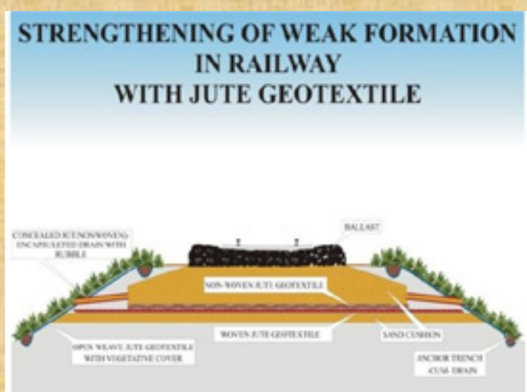
JUTE GEOTEXTILES AS SUSTAINABLE AND ECO-FRIENDLY MATERIALS -GREEN TECHNOLGY USED IN DIFFERENT CIVIL ENGINEERING APPLICATIONS





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