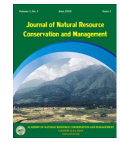
Journal of Natural Resource Conservation and Management
Vol. 1, No. 1, pp 1-6, 2020
https://www.anrcm.org/journal/



Sustainable natural resource management paradigms and research priorities in context to Indian agriculture

Ajay Kumar Bhardwaj[1,*], Raj Kumar[2], Sanjay Arora[3] and Atul Kumar Singh[3]

[1]Pr. Scientist, ICAR-Central Soil Salinity Research Institute, Karnal-132001, Haryana, India; [2]Scientist, ICAR-Central Soil Salinity Research Institute, Karnal-132001, Haryana, India, [3]Pr. Scientist, Regional Research Station, ICAR-Central Soil Salinity Research Institute, Lucknow-226005, Uttar Pradesh, India
**Corresponding author E-mail: ak.bhardwaj@icar.gov.in*

Received : January 11, 2020
Revised : April 17, 2020
Accepted : May 15, 2020

ABSTRACT

Agro-ecosystems sustainability is largely determined by its economic viability and its impacts on the environment and society as a whole. The efficient management of on-farm resources in integration with natural biogeochemical cycles broadens the natural resource base for economic agriculture, and enhances environmental quality. Sustainably managing natural resources also envisages exploring intricate linkages among biophysical, technological, social-economic and environmental factors. For sustainably enhancing growth in agriculture production, there is a need to increase resource use efficiency by integration of agronomy with natural biogeochemical cycles for conserving resources, and to innovate to create efficient technologies for precise application and use of resources. In any case the the solutions must take care of the urgent environmental concerns on priority basis.

Keywords: Sustainability, crop production, agro-ecosystems, climate change

INTRODUCTION

In the Indian subcontinent, the major thrust during last five decades in natural resource management for agriculture has been on putting more area under intensive agriculture with a major focus on meeting the demand for food, feed and fiber. In the famous green revolution which led to self-sufficiency in feeding our population, land and water management played a key role. Some of the major drivers for the success of the green revolution were development of water resources and water availability at farm gate, development of technologies to bring non-productive area under economic production, developing package of practices for high yielding varieties, and to increase fertilizer use and to some extent mechanization. These successes were felt for very short time as there is continuously increasing stress on natural resources through soil, water and climatic changes. Over time, the natural resources which had abundance earlier, have been subjected to different kinds of deteriorating influences and indiscriminate exploitation. At least last two decades saw focus on watershed programs, with main emphasis on natural resource management. In spite of these efforts it has been noticed that improvements have reverted back to the original status, and the impact of development on productivity, equity and sustainability is generally invisible at larger scales (Planning Commission, 2007).

SUSTAINABLE LAND AND WATER MANAGEMENT PARADIGMS

Some of the major and recent concerns in natural resource management, post green revolution, are: land and water resource degradation, shrinking resource base, low input-use efficiency, slow growth in rain fed areas, exhaustive utilization of ground water, excessive use of energy, and environmental pollution. Hence, there is need for further strengthening research programs to enhance growth in agriculture (to meet population pressure) by increasing resource use efficiency, minimizing effects on environment, and integration with natural biogeochemical cycles to minimize inputs. Developing resource use efficient agro-techniques through focused stakeholders needs but synchronized with natural biogeochemical cycles is a key to sustainable agricultural growth and it also addresses our urgent environmental concerns. Reuse of waste water, managing storm water to mitigate floods and use for agriculture, maintaining quality of our water resources, improving soil quality to reduce dependence on synthetic inputs, soil water conservation to sustain rain-fed agriculture, technologies to enhance carbon sequestration, cropping practices to minimize nitrogen losses, and exploration of indigenous and efficient cropping systems are some of the strategic areas of research and development which can be exploited.

Waste water is an abundant resource if managed properly, especially in countries with large populations, and can be the most important water resource in arid environments. The quality of treatment determines it suitability for use in agriculture (Bhardwaj *et al.*, 2007a). The method of irrigation is also largely affected by the waste water quality. Secondary treatment is good enough to provide good quality water for irrigation in agriculture and it also enhanced soil quality (Bhardwaj *et al.*, 2007a; Mandal *et al.*, 2008a, 2008b). In arid and semi-arid regions, plant-based and synthetic polymers can be used along with waste water to increase water use efficiency. Particularly in sandy areas, cross-linked polymers enhance water retention by temporarily storing water during excess as well as reducing hydraulic conductivity (Bhardwaj *et al.*, 2007b). Use of water conserving pressurized irrigation methods adapted to local conditions can provide new and sustainable solutions to water scarcity for crop production in arid and marginal areas. Low energy water application (LEWA) device is one such local innovation for water and energy saving in agriculture (Singh *et al.*, 2010).With growing population, efficiently utilizing the marginal quality waters holds key to counter the growing water scarcity. Water quality improvement methods would though hold key to use marginal waters. For water quality improvement, chemical with physical treatment is one mean which can be effectively used (Bhardwaj *et al.*, 2008a; Bhardwaj and McLaughlin, 2008). Both runoff water and waste water treatment and use minimizes effects on environment (Bhardwaj *et al.*, 2008b) as well as prove as an important resource for farming.

Improving water use efficiency in the cropping systems is yet another area where progress should be made to meet agricultural needs in the water scarce area. Water use efficiency improvement via tillage and residue management can be important tools. Soil moisture mediates effects of hydrological processes on the structure and function of terrestrial ecosystems by regulating the rates of photosynthesis, transpiration and organic matter decomposition (Rodrigue-Iturbe *et al.*, 2007). Understanding the vertical variations in root zone water over the period of plant growth provide invaluable information about the real time plant water needs and its effect on above ground plant growth (Bhardwaj *et al*, 2011a, 2011b). Investment in technologies to manipulate soil water storage and availability is important, thus. Tillage and residue management in cropping systems research are two key areas where the potential is much more than what is already exploited. Ecologically sound management of tillage, residue and fertilizers can not only enhance environmental quality but may also prove economically sound (Bhardwaj *et al.*, 2011c). The economic benefits of such system are longer and sustainable than chemical-intensive systems. Optimization of fertilizer use is an important area which can be exploited to minimize cost and enhance environmental quality (Bhardwaj *et al*. 2019a, Bhardwaj *et al*. 2020. Mixed cropping systems have proven to have synergy by exploiting different sources (spatially and temporally) and more focus should be put on using these concepts in our cropping systems (Bhardwaj *et al.*, 2011c).

Yet another green revolution does not seem likely with the same approaches as followed in the past. A large extent of chemically and physically deteriorated land area (sodicity, salinity, water logging, and loss of nutrients) which has been estimated to be 25.75 Mha in India (Maji, 2007; NRSA, 2005,) and world (434 Mha sodic land, 397 Mha saline land, 45 Mha salt affected irrigated land, 32 Mha sodic agricultural dryland; Source: FAO Land and Plant Nutrition Management Service) presents opportunity for bolstering food security via land reclamation. Developing marginal agricultural land areas have huge potential to meet our growing food demands yet the approach has been minimally exploited. Land quality is inextricably linked with water and energy. Land quality primarily determines the allocation of land to a particular use. By definition, marginal lands are considered unfit for

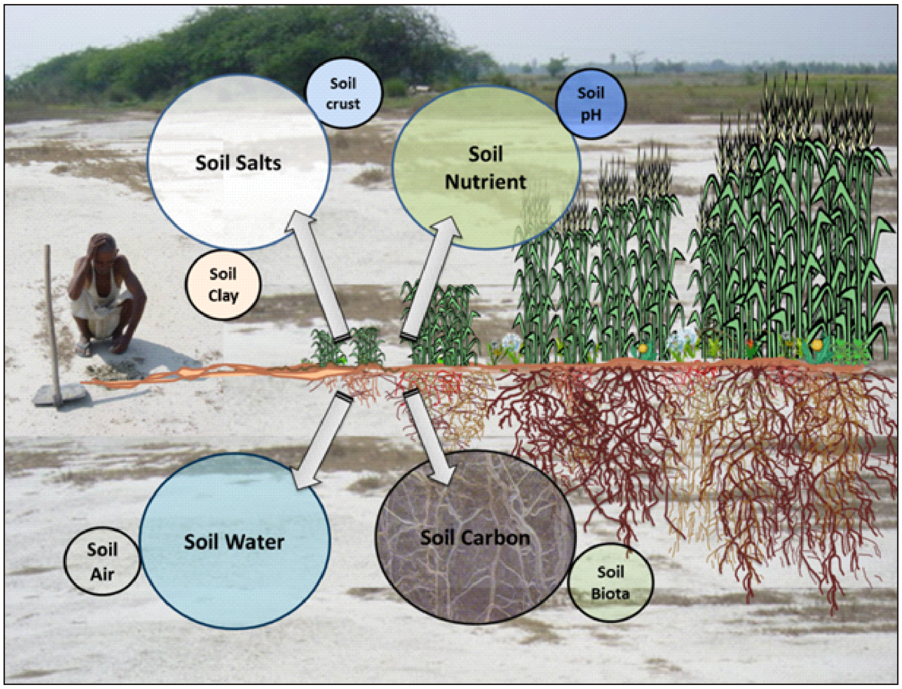


Figure 1. Key elements associated with land and water management for sustainable agriculture

agriculture because of poor land quality. Land marginality is a yield reducing factor for crop production (Bhardwaj *et al.*, 2011d). It takes more water and energy inputs to grow crops on marginal lands compared to prime agricultural lands. To circumvent this barrier, a proper reclamation measure is warranted to improve the soil quality and productivity of marginal lands. The efficiency and availability of natural reclamation materials, which have growing alternative uses, is a concern though. Development of new reclamation materials and technologies holds promise for increased productivity and improved farmer prosperity at national level (Bhardwaj *et al.*, 2019b).

In nut shell, we need more focus on technology development for manipulating plant, water and soil relations at physiological scale as well as taking forward the technology adaptation and adoption at regional level. Enhanced thrust in these research areas of agricultural research can help nation to adequately meet food, feed, fiber and energy needs in this century.

RESEARCH PRIORITIES IN CONTEXT TO INDIAN AGRICULTURE

In view of globalization, climate change and other new drivers in agricultural growth, new parameters need to be designed and prioritized to meet the food security needs of the nation. Some of these priorities have been identified as follows:

Water management

As per National Institute of Hydrology reports the estimated utilizable Surface Water Potential in the country is 690 Cubic km, groundwater Resource is 432 Cubic km. Of this available groundwater resource for Irrigation is about 361 Cubic km and net utilizable groundwater resource for irrigation is 325 Cubic km. With this scenario the country's per capita availability of water estimated to be 1545 cubic meters as per the 2011 census. This shows continuous reduction as the annual per capita availability of water in the country was 1816 cubic meters as per 2001 census (Ministry of Water Resources, 2012). With this rate it is expected that water availability at the national level will drop to water scarcity line by 2025. This requires greater and/or efficient use of agricultural inputs, of which water will be a key input besides land and fertilizer. This requires major emphasis on research which facilitates efficient use of water to meet the increasing demand within limited resources. The areas which need enhanced thrust in water management include:

1. Inventory, characterization and monitoring of water resources including water extraction, storage and its use for efficient crop planning.
2. Total water use (including ET, irrigation and other losses), and ground water recharge under different management scenarios.
3. Management technologies such as residue retention, profile water storage enhancement etc. to mitigate adverse effects of floods and droughts.
4. Water harvesting has received much attention in past yet has not materialized much due to ET and seepage losses and lack of design criteria for harvesting structures. Research should be focused on material research for harvesting structures like ponds and better storage options.
5. Conjunctive use of rain, surface and ground water to integrate these all sources of water and promote use of even poor quality and polluted waters.
6. Development of irrigation technologies such as pressurized irrigation systems for efficient use of water and energy used for its application.
7. Reuse of wastewater, management of storm water and technologies to improve the quality of water.
8. Strategies to safeguard use of groundwater resources in critical zones.
9. Development of water use efficient farming systems.
10. Conservation irrigation system development to enhance water use efficiency.

Nutrient management

At country level the main focus so far has been on fertilizer rate and application doses. Biological management has got enough attention but little progress. Further progress should be made in:

1. Improving fertilizer use efficiency to enhance net return in agriculture.
2. Nano-fertilizers and their safe application methodology.
3. Liquid fertilizers and their precision application methodologies.
4. Precision application methods such as area specific fertilizer formulations to include specific macro and micronutrients.
5. Lack of knowledge in crop residue application/ retention levels and strategies for their use in a cropping system is the biggest constraint in their use in agriculture.
6. Nitrogen management is yet another key to mitigate adverse effects of croplands on environment. Nitrogen doses for a particular crop/ cropping system should include its optimization (form, amount and time of application) for minimizing loses and maximizing uptake by plant.
7. Development of bio-formulations and organic fertilizers should be further exploited.

Cropping systems

Sustainable cropping systems research should be enhanced. Root system characteristics are key to crop acquisition of water and nutrients, however little is known about the roots of a plant. Roots also constitute a large carbon pool in the soil. The interaction of root growth characteristics of the candidate crops with the water availability may provide important information about stress susceptibility and long term suitability of a cropping system. The key thrust areas identified are:

1. Identifying the production system feature within an eco-region and identification of main constrains to sustainable intensification and diversification in these locations.
2. Agro-ecosystems sustainability in terms of resource use and environment impacts should be included in the cropping systems research. Life cycle assessment should the key criteria for evaluating sustainability including all environmental, economic and social components.
3. Water and nutrient flow dynamics for a cropping system should be an integral part of cropping systems research.
4. Cropping systems modeling could be an important tool and should be developed for major cropping systems of country.
5. New and indigenous crops and cropping systems need to be explored and their effectiveness based biogeochemical interactions and natural resource use should be the criteria for evaluation.
6. Integrating inter-disciplinary and inter-institutional team approach to improve production, profitability, employment and sustainability under farm condition through adaptive research and extension.

7. Support strategic crosscutting research and feed into production systems research.

Marginal quality land and water resources

The soil health of crop lands is continuously deteriorating, especially widespread micro-nutrient availability and fast depleting carbon content, resulting in low and decelerated total factor productivity (TFP) growth rates. The present need is to focus critically on improving marginal lands and degraded soils in the country. This will bring new opportunities to get additional area under cultivation. Explore new materials and methodologies for reclamation of marginally productive lands affected by salinity and sodicity, water logging and acidity can lead to substantial progress in increasing food grain production at national level. The key areas for thrust in future are identified as:

1. Development of indigenous reclamation materials with higher efficiency like biopolymers and bio-reclaimants.
2. Enhanced thrust should be given to utilize advanced methodologies like nanotechnology, biotechnology, chemical engineering and microbiology for development of reclamation materials
3. Basic studies on degradation processes should be focused to develop strategic technologies for remediation and to develop predictive models for use at field level.
4. Cost effective drainage and water management technologies for waterlogged areas.
5. Developing advanced techniques for delineation, codification and land capability classification.
6. Generating detailed soil data (physical, biological, chemical and microbial) and mechanisms to update at an appropriate interval based on effective soil testing are prerequisites for all lands under both rainfed and irrigated agriculture to address the issues related to soil health and agriculture production.
7. Developing and popularizing use of marginal water resources for agricultural purposes.

Agroforestry and alternative land uses

Modern agriculture is subjected to risks related to production, prices, markets and financial, and influenced by the institutional and social aspects that often are directly or indirectly associated with weather impacts. In addition, increasing frequency, intensity and duration of severe weather events are posing major challenges to global food security and the livelihoods of rural people. Integrating perennial (tree) component in cropping systems contributes to additional yield/ income as well as reduces crop yield losses under climate change scenarios. The farmers income from agriculture has remain stagnated due to increasing input cost in one hand and decreasing productivity and low price of output/ product on the other hand. In response so-called ‘profitable agriculture’, solutions are to grow highly profitable/valuable trees on farmland to address the issue of farm distress. Moreover, agroforestry has demonstrated great impact on agriculture in terms of improving land productivity and maintaining resources sustainability in the current era. However, following issues should be prioritized for further thrust:

1. Assessment of soil-water dynamics in tree-crop based farming systems.
2. Determination of climate resilience potential of agroforestry models and their comparison with pure croplands vis-a-vis carbon sequestration.
3. Contribution of agroforestry in increasing the farmers’ income.
4. Valuation of ecosystem services of agroforestry systems for developing field protocols.
5. Mechanization of agroforestry practices for obtaining the greater field level impacts.
6. Emphasize should be given to grow high value trees by replacing the existing low value trees.
7. Value addition of tree based products along with the market linkages.
8. Enhancing the quality and productivity of tree spp. through selection and improvement approaches.
9. Applicability of national agroforestry policy and programs at ground level for transfer of agroforestry technologies.
10. Linking of industries with farmers for improving agroforestry extension.
11. Organizing regular training programs on agroforestry for the stakeholders.

Conflict of Interest

The authors declare that they have no competing interests.

REFERENCES

Bhardwaj, A.K., Jasrotia P, Hamilton SK and Robertson GP (2011c). Ecological management of agroecosystems enhances soil quality with sustained productivity. *Agriculture, Ecosystems and Environment*, **140**, 419-429.

Bhardwaj, A.K., Mishra, V.K., Singh, A.K., Arora, S., Srivastava, S., Singh, Y.P., Sharma, D.K. (2019b). Soil salinity and land use-land cover interactions with soil carbon in a salt affected irrigation canal command of Indo-Gangetic plain. *Catena*, **180**, 392-400.

Bhardwaj, A.K., Rajwar, D., Basak, N. *et al*., (2020). Nitrogen mineralization and availability at critical stages of rice (*Oryza sativa*) crop, and its relation to soil biological activity and crop productivity under major nutrient management systems. *J. Soil Sci. Plant Nutr.* https://doi.org/10.1007/s42729-020-00208-y

Bhardwaj, A.K., Rajwar, D., Mandal, U.K. *et al*. (2019a). Impact of carbon inputs on soil carbon fractionation, sequestration and biological responses under major nutrient management practices for rice-wheat cropping systems. *Sci. Rep.*, **9**, 9114. https://doi.org/10.1038/s41598-019-45534-z

Bhardwaj, A.K. and McLaughlin R.A. (2008b). Simple Polyacrylamide Dosing Systems for Turbidity Reduction in Stilling Basins. *Transactions of American Society of Agricultural and Biological Engineers*, **51**, 1653-1662.

Bhardwaj, A.K., Basso B., Hamilton S.K., Jasrotia, P. and Robertson, G.P. (2011b). Water use and hydrological limitations of conventional and alternative biofuel cropping systems. In: The proceedings of The ASA-CSSA-SSSA Annual International Meeting,Oct 16-19. San Antonio, TX, USA.

Bhardwaj, A.K., Goldstein, D., Eizenkot, A. and Levy, G.J., (2007a). Irrigation with treated waste water under two different irrigation methods: effects on hydraulic conductivity of a clay soil. *Geoderma*, **140**, 199-206.

Bhardwaj, A.K., Hamilton, S.K., Jasrotia, P. and Robertson, G.P. (2011a). Water use and water quality implications of alternative bioenergy systems. In: The Proceedings of the Ecological Society of America Annual International Meeting, August 7-12. Austin, TX, USA.

Bhardwaj, A.K., Mandal, U.K., Bar-Tal, A., Gilboa, A. and Levy, G.J. (2008b). Replacing saline-sodic irrigation water with treated wastewater: effects on saturated hydraulic conductivity, slaking, and swelling. *Irrigation Science*, **26**, 139-146.

Bhardwaj, A.K., McLaughlin, R.A. and Babcock, D. (2008a). Energy dissipation and chemical treatment improve stilling basin performance. *Transactions of American Society of Agricultural and Biological Engineers*, **51**, 1645-1652.

Bhardwaj, A.K., Shainberg, I., Goldstein, D., Warrington, D.N. and Levy, G.J. (2007b). Water retention and hydraulic conductivity of cross linked polyacrylamides in sandy soils. *Soil Science Society of America Journal*, **71**, 406-412.

Maji, A.K. (2007). Assessment of degraded and wastelands of India. *Journal of the Indian Society of Soil Science*, **55**, 427-435.

Mandal, U.K., Bhardwaj, A.K., Warrington, D.N., Goldstein, D., Bar-Tal, A. and Levy, G.J. (2008b). Changes in soil hydraulic conductivity, runoff, and soil loss due to irrigation with different types of saline-sodic water. *Geoderma*, **144**, 509-516.

Mandal, U.K., Warrington, D.N., Bhardwaj, A.K., Bar-Tal, A., Kautzky, L., Minz, D. and Levy, G.J. (2008c). Evaluating impact of irrigation water quality on a calcareous clay soil using principal component analysis. *Geoderma*, **144**, 189-197.

Ministry of Water Resources (2012). Per capita water availability. Press Information Bureau, Government of India. Accessed at: https://pib.nic.in/PressReleasePage.aspx?PRID=1604871 on June 29, 2020.

NRSA (2005). Wasteland atlas of India.Ministry of Rural Development and NRSA publication, NRSA, Hyderabad, India.

Planning Commission (2007). Report of the working group on natural Resource Management for eleventh five year plan (2007-2011) Accessed at:http://planningcommission.nic.in/aboutus/committee/wrkgrp11/wg11_agnrm.pdf,on Feb 25, 2013.

Rodriguez-Iturbe, I., D'Odorico, P., Laio, F., Ridolfi, L. and Tamea, S. (2007). Challenges in humid land ecohydrology: Interactions of watertable and unsaturated zone with climate, soil, and vegetation. *Water Resources Research*, **43**, W09301, doi:10.1029/2007WR006073.

Singh, A.K., Sharma, S.P., Upadhyaya, A., Rehman, A. and Sikka, A.K. (2010). Performance of low energy water application device. *Water Resources Management*, **24**, 1353-1362.

Zenone, T., Chen, J., Deal, M., Wilske, B., Jasrotia, P., Xu, J., Bhardwaj, A.K., Hamilton, S.K. and Robertson, G.P. (2011d). CO_2 fluxes of transitional bioenergy crops: effect of land conversion during the first year of cultivation. *Global Change Biology Bioenergy*, **3**, 401-412.