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LINKING AGRO-ECOLOGICAL INFRASTRUCTURE TO CROPPING PRACTICES FOR SUSTAINABLE AGRICULTURAL GROWTH: DO POLICIES AND LOCAL LEVEL INSTITUTIONAL PARTICIPATION MATTER?

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Abstract: *Agro ecological infrastructure for food security through sustainable agriculture is critical in India. Understanding of sustainable agricultural growth coupled with agro climatic farming practices and sophisticated water management seems to have resulted in productivity and positive growth of this sector. In addition, the situation appears to more critical in India, that has a large farm area under rain-fed practices with considerable proportion of marginal farmers, limited capacity of irrigation infrastructure and ailing water management. It threatens the food security, livelihoods in general and the environment in particular. Given this background, the article highlights democratization of agriculture policy and practices. Therefore, the urgency to adopt an agro-ecological agricultural performance with the integration of productivity in terms of efficient and participatory use of water from different sources within the hydro climatic framework. It also provides an understanding of the necessities of less water consuming crop yield adhering the diversification of agriculture. Consideration of these premises to the conclusion that technological intervention inside farmer knowledge helping agriculture precisely smart and sustainable.*

Key words: Agro Ecological Infrastructure, Cropping Practices, Sustainable Agricultural, Policy

Introduction

Agriculture is the largest source of livelihood for the working people in India, although its share in gross domestic product (GDP) has declined over time (Gadgil and Gadgil, 2006). From the last four years, the scenario of agriculture no even better, and the average growth rate was 2.1 (Economic Survey of India, 2018). However, agrarian crises were accentuated by low growth with declining productivity and high dependence of population on lower farm income. This unprecedented crisis with stagnation or decline in rural employment growth and, as a result, food security and employment opportunities for the rural poor have terminated (Siddiqui, 2015). Although the agrarian nature of the rural economy in India is well recognized, inadequate infrastructure support, especially with limited irrigation facilities leading to lower productivity with policy bias, institutional constraints and mismatched agricultural planning over the years carried slow down the pace of development activities. In addition, input-intensive farming methods have posed serious threats to the sustainable development of Indian agriculture as a result of loss of biodiversity, reduction in groundwater levels and degradation of soil quality. Frequent incidents of drought and unseasonal and heavy rains and floods have also affected the livelihood of rural people, especially those living in dry areas where irrigation facilities are low. The latest reminders of agricultural vulnerability are frequent droughts in 2014 and 2015 due to the monsoon deficiency (Gautam, 2016). Hari et al. 2018 evident that, climate change could reduce farm incomes by 15-18 percent on average, and by as much as 20-25 percent in unirrigated areas in India. Hence, assessing the vulnerability of agriculture, climate change is a prerequisite for the development and dissemination of climate-smart technologies. This information is essential for decision makers and planners to devise strategies to address the adverse impacts of climate change and to prioritize areas that are vulnerable to resource allocation (Shinde and Modak, 2013).

As the land cover changes sometimes gradually or many a cases anthropogenic in an abrupt rate, the information regarding land use and land cover (*LULC)* changes has an important role to play local level planning basically in agriculture. Agro climatic zone and region-wise specific factors causing low productivity as environmental challenges have also been identified. As India has a large geographical area with a series of agro-climatic regions, particularly faced a severe problem regarding coping behavior against climatic variability in agriculture sector. It leads to the negative influences on the yield of rice, wheat, pulse, and soybean. Researchers and policy makers always overseen that an extensive adaptation and mitigation strategies by the farmers' for confronting the detrimental impact of climate change (Dagar et al. 2012). Sahu and Mishra (2013) suggested a bottom-up approach in a particular socio-economic and agro climatic set up. It's one of the available adaptive plans for sustainable agriculture growth. This approach has a long term focus on sustainability of agriculture and resource reserve; and also accentuated the inter-sectoral linkages at regional and inter-regional levels.

This paper reviewed how agro ecological infrastructure coupled with proper cropping practices and local level participation for managing the infrastructure to promote sustainable agriculture growth in India. The paper has six sections. Justification of agro ecology specific infrastructure for sustainability of existing agriculture in the variable nature of climate is discussed in next section. The third section presents the relevance of local level participation from governance to management of common poll resources like irrigated water in agriculture. The fourth section deals with the relation between different sourced irrigation methods and cropping practices in Indian agricultural scenario. The subsequent section addresses the diversification of cropping system for sustainable use of water resource in different agro ecological region of India. The last section concludes summarizing and highlighting policies winding with the changing nature of climate regarding sustainable agriculture growth, which will foster per drop per crop aspiration in future.

Agro Ecological Infrastructure for Sustainable Agriculture

Environmental change and its effects on water resources and agriculture practices are a noteworthy force with which India will have to adapt in the twenty-first century. Advance warning systems can play an active role in assessing and controlling risk due to uncertain climate change events. Thus, appropriate cropping systems and practices have been critical aspects of Indian agriculture, particularly in rainfed agriculture. Hence, there is no practical consideration for sugar cane in Marathwada, western Maharashtra, northern Karnataka, or the Cauvery belt in Tamil Nadu, or even in the Gangetic plains in west Uttar Pradesh, eventually, wheat–rice cycle in northwestern India (Thakkar, 2019). So, Agro ecological management approach desperately needed to achieve a sustainable agricultural ecosystem utilizing local resources and wisdom in production (Koohafkan and Altieri, 2011), which belittles costs of production and gives small scale farmers more welfare. Apart from the twenties categorization of Agro-ecological zones delineated by Indian Council of Agriculture Research (ICAR), we divided two categories of agro-ecological jones of India, i.e., irrigated and rainfed. Then, rainfed further shared high and low potential area (Fan et al., 1997). Productivity in terms of cropping practices, irrigation types, and other socioeconomic indicators differs between high and low potential areas of the rainfed zone.

Indian Council of Agriculture Research (ICAR) and Planning commission allied agro ecological or climatic zonation are miss fitted in micro scale agricultural studies, as do not consider micro-climatic variables such as soil, weather and the availability of irrigation water that can be used to determine agro-ecological zones within states. In the case of Punjab state of India, the cropping pattern in all these subzones is different as of variances in rainfall, underground water, soil type, and climate (Gill, 1992). Hence, based on agro-ecological evaluation and specific socio-economic characterization, optimize resource, policy, and technology in an integrated fashion to achieve a sustainable agricultural future. Thus, ago-ecology has emerged as a dominant approach used to study, confirm, and propose alternative low-input management of agro-chemicals. The primary goal of ago-ecology is to address the sustainability problem of agriculture. Argo-ecology provides environmental guidance to guide technological development in the right direction. Agriculture proposes to restore landscapes surrounding farms, which improve the ecological matrix and many functions such as natural pest control, soil and water conservation, climate control, and biological control. Argo-ecology is a powerful systemic approach that helps us explore the link between agriculture practices, planning, governance, resource management and health of ecology that contributes to rural livelihoods in changing climate. Hence, sustainable agriculture should ideally produce good crop yield with reduced impact on soil and water quality. Therefore, redesigning the ago-ecosystem to maximize the climatic, ecological, economic, and social synergies among them, while minimizing the conflicts in agricultural growth in a long run. (Figure.1)

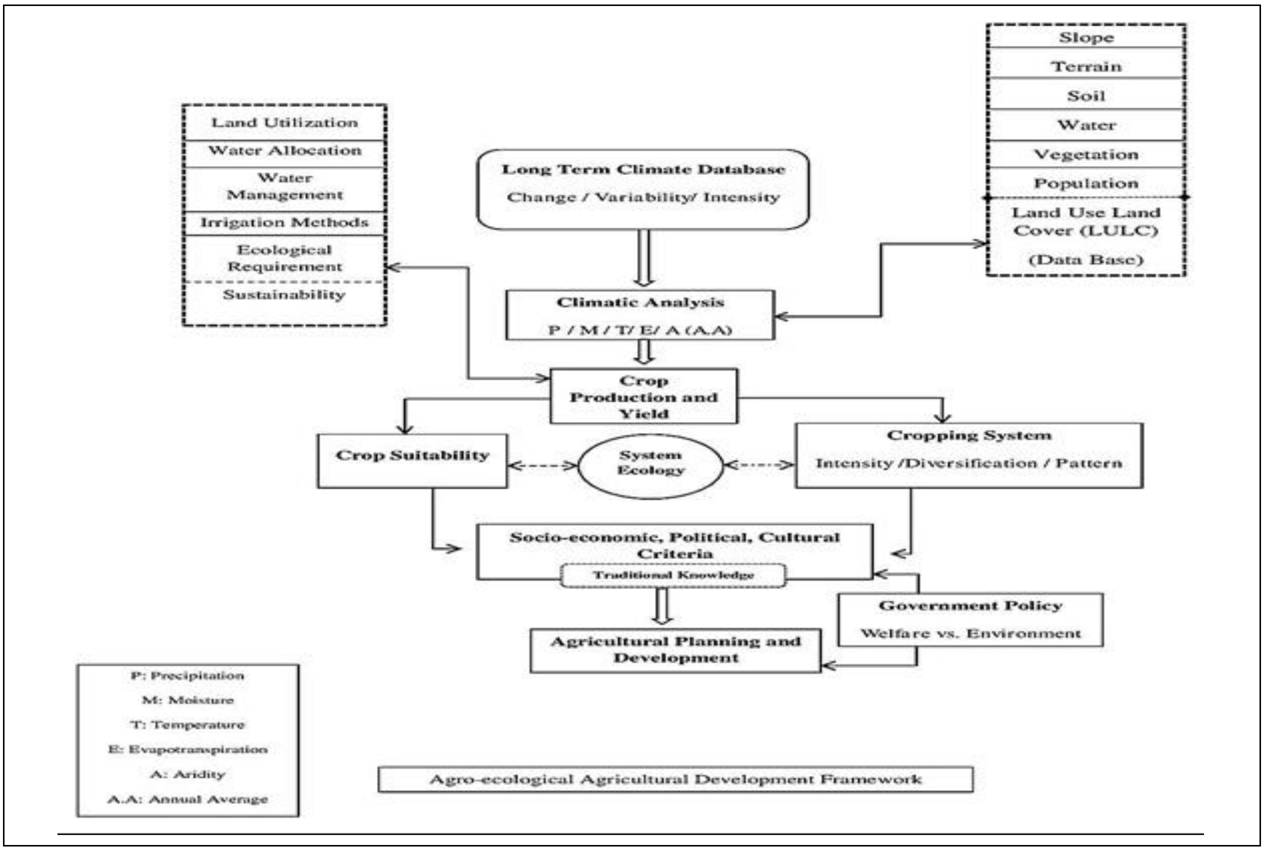
There is an urgent need to acquire an agro ecosystem’s approach, such as integrated ecologically crop with soil and water management. Given this backdrop, therefore, a fundamental rethinking of food production calls for a rational partnership of sustainability, water resources that will maintain and enhance ecosystem function between subsystems.When it is seen across the states, a more substantial number of state's area under rainfed practices, home to the majority of rural poor and marginal farmers are expected to be the worst affected by the changes in climatic conditions. Policy makers are increasingly looking for a rainfed area for future agricultural growth. A seminal work by Raina (2012) foregrounded noticeable changes of knowledge, policy, and practices of the rainfed area where considerable proportion of marginal farmers poorly adapt to the changes in climatic conditions. In addition, suggested, from the practice of “production per hector” to "more crop per drop" i.e. increasing productivity per unit of water. Agriculture has to achieve more 'crop per drop' to increase water efficiency by modernization of irrigation technologies with on firm soil moisture management. *Pradhan Mantri Krishi Sinchay Yojona* (PMKSY) scheme has allocated 50,000 crores over five years in these areas. This is very important considering that some of the states have perhaps the utmost successful three-tier panchayats institution in the country resulting in active and democratic local level institutions to utilize local resources and expertise optimally. Participation is to improve the institutional structures and rights behind participatory irrigation management (PIM) and water user associations (WUAs).

Local Level Institution in Agriculture Growth

The scarcity and depletion of surface and groundwater resources is a common law worldwide and sustainable management proves to be extremely unusual. The main reason for this misuse of water resources is that water is a common pool resource with a high environmental externality (Gracia, 2010). Therefore, the approach to solving management problems involves cooperation between stakeholders through the right democratic institution and organizations. Numerous irrigation systems appear qualities of common pool resources (CPRs) and are overseen as a fundamental property. Frequently, a group mutually keeps up a foundation to such an extent that the speculation of an individual creates positive externalities for the entire group. The standard hypothesis predicts that it indicates free-riding behaviour and, thus, low-interest in the asset system (Olson, 2009).

A large numbers of *Water User Associations* (WUAs) are managing 13.16 million hectares of irrigated land in India (NITI Aayog, 2015). Only fifteen states have successfully implemented the *Participatory Irrigation Management* (PIM) Act (Dev, 2016). However, the positive functioning of WUAs has been reported in parts of India such as Maharashtra, Gujarat, Andhra Pradesh and Odisha. Initially, the experience of WUAs in Andhra Pradesh and Odisha was encouraging; especially in the case of providing irrigation to farmers of tail-end watershed. An adverse impact of *Participatory Irrigation Management* program as the regarding WUAs to be further operative in case of a minor project whereas it is weak in case of major and medium projects in the state of rainfed practices (Ghosh et al. 2010). Lesson from the plan of *Pani Panchayats* in Odisha, participatory irrigation management in local scale provides equitable, assured, and timely irrigation to a homogenous or heterogeneous group of farmers. It incorporates a collection of water rates, distribution among the stakeholders, and regularly conveys the maintenance of the systems (Behera and Mishra, 2018) to facilitate the greater cropping diversification with achieving farming capacity. *Kakatiya Project* in the newest state of Telangana in 2014 harness the benefit of tank irrigation by increasing command area of Godavari and Krishna basins, revival and restoration of minor irrigation, water supply for irrigation to the upscale opportunity of agriculture. However, the quality of implementation and approachability of the village community has not been uniform across the district of Telangana. It is evident that, the operation of tanks basically insouthern part of India renders maximization of the positive impact in natural resource management for sustainable livelihood. This promotes the interest of resource management of the user community and continuous use of public resource significantly in a decentralized and judicial manner (Shah and Verma, 2018). Apart from this, there is no information regarding how much takeout from the waterbodies (tank, pond, river, lake, wetland) can be allowed to keep the water sources, i.e., the carrying capacity make to be sustainable and manageable.

Figure 01: Agro ecological framework for Sustainable Agriculture Growth (By Author)



Rural population significantly depends on water for agriculture. The socio economic value of water is also important, especially for rural residents. However, the governing of common pool resources such as water in which numerous people uses such resources that they form units of resource where one person uses the quantity of resources available to others (Basurto and Ostrom, 2009). In addition, many common-pool resources are so large that multiple actors can use the resource system at once and are too expensive to exclude potential beneficiaries is very costly. Larson and Soto (2008) suggested, natural resource decentralization with an emphasis on water treated as common property resources, thus it should be prompted in community-based resource management which intersects by good governance, democracy, development, and poverty alleviation. Community beliefs, value system, norm, and practices may be functional in dealing with the current issues, which adopt and adapt to the emerging in management perspectives. The ultimate success and sustainability of any participatory framework of agriculture management depend on common interest to collective efforts and good leadership with well-defined property rights, which are bypassing to the factor of political half-heartedness and class and caste bifurcation and indeed elite capture comprehensively. So, transfer of the management of irrigation practices from the government to the formal or informal farmer's association or club a pivotal policy that has resulted in a possible impact in a spatio-temporal scale.

Cropping Practices towards Irrigation

An appropriate coping strategy possibly requires diversifying the land use for the cultivation of crops, which are more climates resilient, remunerative and environment-friendly. Such local level institutions can play a crucial role in this regard. Sometimes, kharif crops experienced the flood factors as well as the prolonged dry spell and in contrary the Rabi corps experienced high transportation (ET) and moisture loss of the agro-ecological system (Bhattacharya et al. 2019). Generally, surface water storage fruitful for groundwater recharge through aquifers fillings in a long run. But due to proper management of the water resources on surface area and cropping practices by the farmer propelled the loss of soil moisture through evaporation with transportation. Therefore, reliability on groundwater storage will acquire more considerable significance for India in changing hydro-climatic regimes. (Shah, 2009).

Groundwater based irrigated agriculture in India started to take off from Green Revolution by using the high yielding cropping behavior and input intensification. It has promoted groundwater-driven irrigation expansion. It is estimated that more than 70 percent of India's food grain production comes from irrigated agriculture, in which ground water plays a major role (Gandhi and Namboodiri, 2009). The Central Ground Water Board estimates the current annual groundwater draft to be 230.6 BCM. Subsidies on energy have cut the cost of electricity required for groundwater farmingto close to zero, which undoubtedly promotes groundwater use. This is due to increased exploitation and rapid deterioration of water table, deterioration of water quality, and increase in frequency of well failure and rapid investment and operational costs. But microclimatic variation and agro climatic water supply demand governance, in terms of infiltration, vegetative cover, mean temperature, low moisture, and case explicitly justified subsidy catered sustainable water governance. Integration of groundwater development and optimal use of surface water bodies like tanks is a precondition which minimizes the externalities and plies for sustainable water resource management (Reddy, 2005).

When, development opportunities in more favorable area seems fatigued, then increasing interest to improve productivity in rainfed areas based on equity, efficiency and stability will emerge. Thus, India has adopted an integrated watershed progaramme, as a viable strategy for improving productivity in water-stressed areas. Thus, the effects of watershed interventions in India are directly linked to increased groundwater availability for irrigation making groundwater management one of the major issues for the success and sustainability of watershed programs. However, watersheds are generally inhabited by a diverse group of farmers with fragmented land use patterns and resource use rights. While social and biophysical miscellany inside the watershed reduces the potentiality of collective actions, erratic use and utilization of groundwater accelerates its reduction.

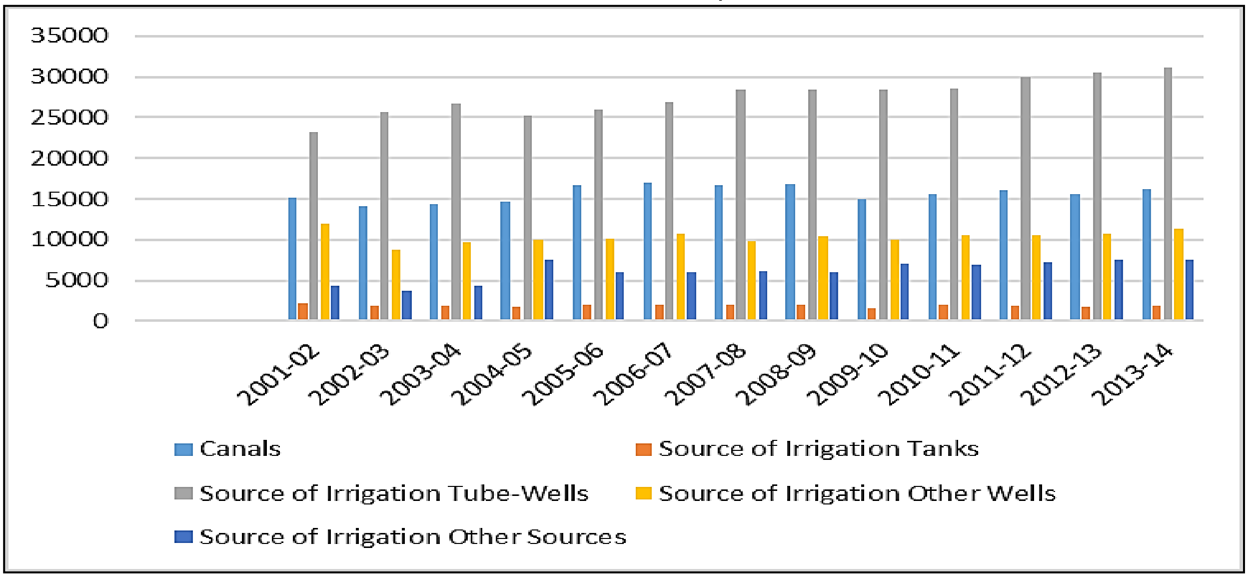
Upper catchment or lower catchment water governance will have the most beautiful effect on local hydrology in general and execution of tanks in particular. Better utilization of land in the catchment development (in situ water harvesting), which further prompts a decrease in surface runoff part of that spillover effect in the favorable soil profile. Suitable tank structures with smooth rehabilitation, channel, distributaries have a positive influence on tanks productivity (Jana, 2012); but the eastern part of India, tank are survived as a morbid ecosystem structure of water practices (Jana, 2012). Even though water system tanks have significant legitimacy in improving the natural, biological, and socioeconomic status of the general population who are relying upon it, the declining execution of tanks and related livelihood outcomes and adapting methodologies have not been thoroughly inspected.

It has been found that the share of cropped area under non-food grains (high value crops) has increased considerably in the last two and a half decades. Small and marginal farmers constitute around eighty percent of the total farm households (Dev, 2012). Therefore, the future of sustainable agriculture growth and food security, in India, depends on the performance of small and marginal farmers. The small and marginal farmers depend on a small piece of land and have no alternative sources of employment and income. However, there is evidence of these small and marginal farmers attempting to cultivate a variety of resilient climate crops. From the existing literature study, it appears that an abundance of natural resources alone is neither necessary nor sufficient to facilitate the growth of the agriculture sector. While developmental policies and institutions are likely to influence the relationships between resource abundance and growth of agriculture in respect of their conservation, management, and uses, rational behavior of economic and social agents are also crucial in this regard.

Evidence also suggests that, the severity of poverty and social exclusion are caused mainly by a level of control over and rational use of these resources instead of their endowments. For example, Small farmers are looking for opportunities to intensify and diversify their agriculture, which require irrigation throughout the year (Shah, 2009). Tanks and canal systems are impotent to meet this need, but are groundwater wells. The increasing dependence on groundwater and decreasing areas under surface irrigation is the major trend in Indian irrigation nowadays (Figure 2). Efficiency and impacts are likely to differ across various types of irrigation structures, mainly due to variations in physical settings, agro-climatic conditions, and socio-economic setups.

Furthermore, it has been observed that the rapid development of minor irrigation India has resulted in greater extraction of groundwater, resulting in dark areas, which have significant implications for local ecology. It is mysteriously noticed, the sustainability of irrigation systems is adversely affected in terms of water use efficiency and equity (Dev, 2016). One of the studies also indicated that more than 50 percent of the farmers were willing to pay additional charges for assured irrigation supplies (GOI, 2010). While irrigation through watershed development can lead to a win-win situation by complementing natural resource conservation and agricultural productivity, property rights are expected to provide incentives for sustainable farming practices and promoting inclusive growth of agriculture.This is where the cogency of fortifying the science and policy interface, the intersected topic of conflict resolution.There is an urgent need that, our plans, projects, and programs get tailored keeping this reality in mind and work to protect groundwater recharge, enhance recharge where possible, and most importantly, regulate the use of groundwater (Thakkar, 2019). *Mahatma Gandhi National Rural Employment Guarantee Act* (*MGNREGA*) created assets like farm form, contour trenches, land labeling, binding, orchard field would be useful for drought proofing convergence initiative for sustainable water cum livelihood generation.

Figure 02: Net Area under Irrigation by different sources based on the data from Central Water Commission, 2015



Cropping Practices to Sustainability

In recent years, there have been concerns about the economic and ecological sustainability of profit-oriented cropping practices. The farmers do not have a better alternative for their degrading land and also water underneath. Hence, initiatives should be taken for guiding the farmers towards the choice of appropriate cropping patterns for more judicious use of water. Some studies suggest that, valuing water at its opportunity cost will provide an incentive for farmers to move from water-intensive rice to high-value, less water-intensive crops. Also wet season rice; to ensure a market-based approach to water allocation, from farm crops to fruit and vegetables to other environments, will increase diversification and commercialization of irrigated agriculture by increasing farmers' flexibility (Rosegrant et al.1995). To put Indian agriculture on a sustainable path, the strategy should be to shift from a relatively high risk rainfed to low risk assured irrigation-based cropping system. Also, crop diversification can be another effective instrument in that direction. Policy implications for crop diversification as a necessary strategy for agricultural development to improve agricultural resources, productivity and efficiency in agriculture in India (Birthal et al. 2007). Gifted with the exclusive ability of nitrogen stabilization in the soil, carbon sequestration, soil isolation, low water requirement, and greater handling capacity, pulses remain an integral part of sustainable diversification of cropping practices in Indian agriculture (Acharya et al. 2011).

The Accelerated Pulse Production Program (APPP) under the *National Food Security Mission* (NFSM), increase in both minimum support and procurement price for pulses, Rabi pulse production. Therefore, integrated development of 60,000 villages under pulse production through *Rashtriya Krishi Vikas Yojana* (RKVY) and other initiatives have modified to height the pulse production from 2017-2018 million tones to more than 25 million tons in the current financial year and moreover pulses which currently is 764Kg/ha as compared to a global average productivity of 909 kg/ha (Directorate of Economics and Statistics, 2018). With the availability of water, with its more economical and equal use and rational choice of crops, it should be possible to irrigate more land now; it would be even more, if the water was taken into consideration of its ecological assessment or its scrappy value is kept. Moreover, not in the face value at which the farmer receives it. So, there is a need to develop an optimal crop plan and water resource allocation scenarios under hydrological uncertainties in relation to various agriculture (rain and irrigation base) i.e.precision, organic, zero tillage and weather (monsoon and winter).

Conclusion

The Sustainable Development Goals (*SDG2*) requires reliable and accountable institutions, inclusive and effective decision-making processes, and societal equality and equity, which are achieving success in a long run basis. The interdisciplinary and dynamic perspective called for technology design and development efforts under the direction of poverty reduction and sustainable management in agriculture. Adoption of micro irrigation practices maintaining the minimization of cost and improving fertigation schedule (law of minimum input in horticulture practice) pursues the public, private partnership for paving the way the sustainable irrigation intervention in a participatory manner. Incorporating inclusion in decision making in crop choices and marketing in agricultural development not only enhance the productivity of agriculture but also empowered the life of marginal people of the rural area in the field of national food security. Ensuring climate-resilient agriculture and agro-biodiversity in India both builds and depends on stronger communities that can participate more actively in sustainable development and rationally achieve global food security.

Furthermore, traditional knowledge of the farmer with the latest scientific knowledge and practices can yield productive food systems substantially. Environmental issues are usually complex, interconnected, multidimensional, and widespread on spatial and temporal scales. So, the seriousness and complexity of these issues has prompted the creation of comprehensive approaches to resource management in India. Comprehensive and sustainable soil, land, water management are requiring to lessen the conflict on ecosystem. Both risk and uncertainty contribute to the selection of appropriate management practices by decision-makers in agriculture. Hence, develop an accessible database on climate, soil and water use and crop yields to assess and monitor overall performance of agro ecosystem in a long run. Furthermore, water charge may be considered a suitable policy option to reduce the water level in semi-arid areas, where intensive cropping patterns are expanding. Additional fees for irrigation, if differentiate on the basis of crop-water demand, may encourage farmers to plant crops that consume less water. Water markets alone also cannot improve water use efficiency and water savings unless farmers use less water in agricultural activities. Integrated decision processes at the national and regional levels are desired to achieve synergy. Moreover, there is an hour to coordinate response for addressing vulnerabilities with committed engagement of farmers, agricultural support services, institutions and enabling policy to build sustainable livelihoods resilient to climate risks on smallholder farmers. Restructuring of agro environment system cross cuttingly encourage the economic, environmental and social indicators. Now, agriculture is commanded that is ‘doubly green’ which should both protect the environment and expectant to deal with trade-offs among agriculture, water, energy, land and climate change.

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