Extension Methodologies for enhancing adoption of Soil conservation and agronomical technologies in Watersheds

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Introduction

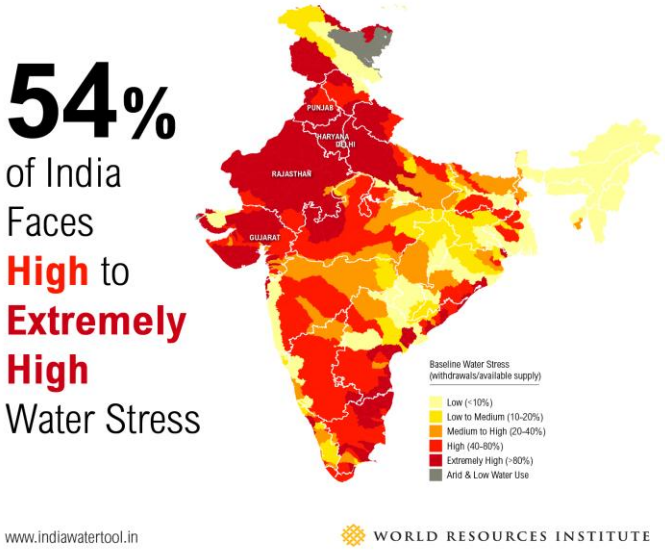
Soil and water are important natural resources in agriculture. India is a less water available country. The country has more than 140 million ha of cultivable land. Among the cultivable lands, 48 percent of cultivated land remains under rain fed farming. These agricultural lands provide food, fuel, fodder and life support system based livelihoods to landless, small and marginal farmers. At the same time, agricultural land fertility has been depletion due to various land degradation processes like soil erosion, overgrazing, general mismanagement, improper utilization soil and water conservation management practices, etc. These processes lead to soil degradation and deterioration of its' physical properties of soil structure, texture, elasticity, bulk density, etc. The natural soil weathering process takes 600 - 1000 years to form 1.0 inch of top soil in the earth. It has been reported that in India, 5,334 million tons of productive soil are lost every year through soil erosion. The rate of loss is 16.4 tons per hectare every year (CSWCRTI study 2010). It is because of non-judicial and imbalanced use of inorganic fertilizers (NPK), wrong irrigation practices and excessive use of irrigation water lead to soil salinization. Further, excess usage of insecticides and pesticides deterioration of soil fertility / nutrient deficiencies , affecting crop productivity. Hence, promotion of judicious use of chemical fertilizers, soil test based balanced and integrated nutrient management (INM), Integration of inorganic with organic manures like farmyard manure (FYM), compost, bio-fertilizers and green manuring should be emphasized for scientific and integrated management of the natural resources like soil, water, environment and ecology.

Besides, farmers in non-irrigated areas, facing worrying natural conditions. Hence, the farmers follow traditional, low-risk cultivation practices that typically yield low returns. It reduces national agricultural productivity at the macro level. It also reduces the amount of water consuming crops like millets, pulses and oilseeds due to the improper utilization of natural resources, especially the soil and water in that particular semi- arid agro ecology. Several regions like the states of Maharashtra, Karnataka, Telangana and Tamil Nadu are facing huge water distress. In this regard, the economic feasible, environment friendliness, socio-cultural acceptance, sustainability and location specific suitable soil conservation and agronomical technologies adoption in watersheds are the solutions for enhancing and sustainable agricultural production in the rain fed areas (Ghose et.al., 2008). Besides this, the National Watershed Development Programme for rain-fed areas, Integrated Wasteland Development Programme and the Pradhan Mantri Krishi Sinchai Yojana are a national mission to improve farm productivity and ensure better utilization of the resources in the country.

Need of Watershed Development and Management

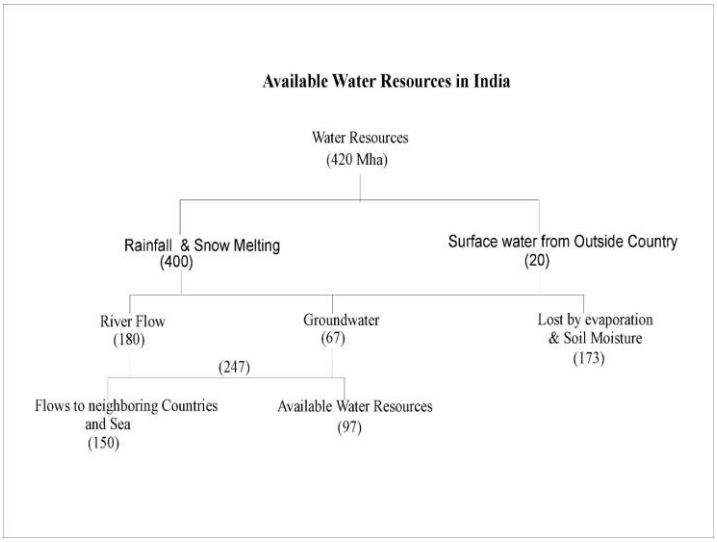
Watershed is a geo-hydrological unit comprised of all land and water within the confines of a drainage divide. It is a land area that captures rainfall and conveys the overland flow and runoff to an outlet in the main flow channel. It is a topographically delineated area draining into a single channel. In order of size, the watersheds are classified as micro watersheds, sub watersheds, watersheds, catchments and river basins.

Water Stress Mapping in India



In India, the watershed management is one of the critical factors for improving agricultural production. Most of the arid and semi-arid regions have concentrations of eroded and degraded natural resources. It affects soil, water and vegetation loss of vegetal cover, followed by soil degradation through erosion, has resulted in lands lacking in water as well as solid nutrients. In India, out of a total geographical area of 329 million hectares, 57% of the area is suffering from soil degradation as a result of harsh climate

condition, less effective utilization of soil resources, deforestation, etc.



(Source: Kakade. B.K. BAIF)

This can be done by following the activities, strategies, and appropriate technologies under the integrated watershed management practices to promote efficient and sustainable use of rainwater, conservation of soil, improve land productivity, regenerate vegetation cover on denuded wastelands, promote rain fed farming systems and sustainable agriculture. Improved livestock productivity and equipping rural communities for sustainable management of the natural resources.

Soil conservation and agronomical Technologies in Watersheds

I. In-Situ soil- water Conservation Measures

1. **Afforestation practices:** Planting tree species nearer to the farm lands. Inter cropping of forest trees with food crops meet timber needs the future.
2. **Drainage Line Treatment :**The treatments on natural drainages in a watershed start from the beginning of a small gully by plugging it to stop erosion using locally available materials such as stone, soil, and live hedge. It reduces runoff velocity and recharges the ground water.
3. **Bench terracing practices:** Terracing is usually practiced on slopes ranging from 6 percent to 33 percent. The material excavated from the upper part of the terrace is used in filling the lower part. It reduces soil loss and runoff significantly on the farm lands.
4. **Contour bunding:** Contour bunding is the farming practice of planting across a slope following its elevation contour lines.It is a traditional and low-cost method of soil conservation practices for sloppy land; it promotes water retention and prevents soil erosion.
5. **Retention of runoff by practicing suitable drainage mechanism:** Water conservation through construction of small ponds in lower elevated areas under farm conditions. Usage of the water in upland areas and the pond attracts birds and wild animals for biodiversity conservation. (Muralikrishnan, L. 2015)

II. Agronomic cropping system-based soil and water conservation practices

1. **Choice of crops and cropping system:** The choice of crops and cropping system is based on the topography and environmental importance. This maintain the soil fertility for sustainable agriculture an effective nutrient cycling process.
2. **Fallowing of land:**Leaving the agricultural field for not practiced crops for particular agricultural crops. It conserves the organic matter and natural bio moss to improve the soil health.
3. **Conservation tillage:** This is a type of tillage when converted to no or low tillage operations, reduces the loss of soil and water in comparison to conventional tillage. It improves the soil texture as it retains plant residue and increases organic matter.
4. **Alternate tillage:**Tillage in alternate rows to rotate the leaf residue on the soil. It reduces weeds and helps nearly 50% reduction in field activity. It also stabilizes, soil surface and reduces soil compaction.
5. **Cover cropping:** Cover crops play a central role in managing cropland soils in biological farming systems. It reduces soil disturbance due to wind erosion and helps to improve soil moisture conservation. Farmers make use of cover crops for dynamic accumulation of soil nutrients, nematode control, soil loosening, soil building, soil protection and nitrogen fixation.
6. **Mulching:** applying plant residue and organic materials like Farm Yard Manure (FYM) to the soil surface. It reduces soil erosion and weed competition thereby reduction of the soil compaction.
7. **Crop rotation:** Crop rotation is the sequential planting of crops. Crop rotation minimizes the pests and diseases. The changing of crops in a sequence tends to decrease the population level of pests. It entails the planned association of two or more plant species in close proximity. In addition to beneficial

associations, companion planting increases biodiversity on the farm which leads to a more stable agro ecosystem. Ex: cowpea + cassava + banana + yam is a practice of two-year crop sequence

8. **Conserving the microorganisms:** application of bio fertilizers and protection of existing microorganisms in the cultivated land. It helps to improve the soil fertility status in eco-friendly manner.
9. **Appropriate irrigation practices:** Use of micro-irrigation systems like drip, sprinklers or buried line in crop cultivation avoids over-irrigation. It conserves the quantity of water usage and enhances water use efficiency. It also reduces weed population, which in turn reduces the need for tillage and reduces soil compaction.
10. **Mixed cropping system**: Growing two or more crops simultaneously with no distinct row arrangement. It ensure efficient utilization of sunshine and soil fertility maintenance. It is an efficient way of using land in rain fed cropping systems.
11. **Multispecies plantation:** Planting of various crop species on the same unit of agricultural land. It stabilizes soil on erosion-prone hillsides and reducing the amount of soil sediment. Ex: Coconut + jack + silver oak + pepper + coffee + banana plantations.
12. **Alley cropping:** It is a method of planting, in which rows of a crop are sown between rows or hedges of nitrogen-fixing plants, the roots of which enrich the soil.It fixes the atmospheric nitrogen and improves soil fertility. Ex: cultivation of the pulse tree, like Cinchona.

III. Vegetative soil and water conservation Practices

1. **Agave plantations in the areas prone to landslides:** Agave plant is grown as hedge plants for soil and water conservation. It protects the soil from soil erosion. And so, the agave plant yields quality fiber useful for preparation of ropes, mats and decorative materials.
2. **Treatment of land slip areas with vegetative barriers:** Planting the grasses to control soil erosion in the narrow land slip areas. It protects the soil from the landslides and acts as a biological drainage hole of the land slip area. Planting of bamboo trees across the land slip areas in hilly regions.
3. **Staggered trenching with vegetative methods:** Staggered trenches are generally designed to control the runoff problem. In staggered trenching, trenches are located directly below one another in alternative rows. Contour trenches are used both on hill slopes as well as on degraded and barren lands.
4. **Strip cropping:** Planting agricultural crops in more or less parallel strips across the slopes. Improves organic matters and nutrition addition, controls runoff, reduces soil erosion and maintains the soil fertility.
5. **Regeneration of vegetation:**Maintenance and regeneration of vegetation cover reduce windblown dust and control soil erosion in arid and semi-arid regions.
6. **Silvi-pastoral practices:** Silvi-pastoral systems seem to be the most viable option for farmers in the arid and semi-arid regions. The silvi-pastoral systems with combination of suitable native grasses/legumes and fodder crops provide decent income generation livelihoods to resource poor regions. It also supplies quality fodder for a huge livestock population with an adequate forage requirement. Ex : Sorghum + fodder grass + Acacia nilotica.

IV. Soil fertility based agronomic Practices:

1. **Green manuring:** Green manuring is a biological farming practice. It involves the soil incorporation of any field or forage crop while green, or soon after flowering, for the purpose of soil improvement. Ex: cultivation of peas and mustard crop in the potato fields.
2. **Green leaf manuring:** Incorporation of green leaf manure from unwanted leguminous tree leaves and branches in to agricultural lands. It supports soil nitrogen enrichment. Application of a leguminous green leaf manure crop like *Sesbeniarostrata*.
3. **Incorporation of crop residue in to soil:** Crop residues should be incorporated under field condition, through mulching practices. It also sustain the soil fertility.
4. **Organic manure application:**Organic manure applications improve the soil fertility status for sustainable agriculture.: Application of FYM + poultry manure + bio fertilizers
5. **Integrated Nutrient Management:** Integrated Nutrient Management (INM) is an ecosystem approach to utilize a variety of methods and techniques like, cultural, biological approach to sustainable soil fertility management. It is an integrated application of bio-fertilizers, organic manures, green manures and organic fertilizers.

At the same time, indiscriminate use of inputs coupled with improper management practices over a long period has resulted in land degradation and decline in its productivity. Now time has arrived to source out modern technologies for improved economic and environmentally sustainable crop production. Among the technological developments, Precision Farming (PF) has emerged as a promising option for increasing and sustaining the agricultural productivity in India (Muralikrishnan, L 2012).

Precision Farming in India:

In India, 90% of small and marginal farmer's adoption of all precision farming technology is difficult. But, it is possibly, proper adoption strategy. In the year 2007. The Tamil Nadu Agricultural University conducted precision farming project and up scaled and out scaled in larger areas of the state. There, they recommended some key technologies of precision farming that are easily adoptable by small and marginal farmers and the Institute also provided financial and technological support for the success of the programme. Here, we are recommending to other region farmers that semi-arid based ecologies can also adopt these technologies for sustainable production and conserve the natural resources like soil and water.

Key Precision Farming Technologies (4Nos) adopted by TNAU (2008):

Remote Sensing Technology

Making use of the GIS, the physiographic map, soil map and land use map with the support of Information and Communication Technology and Remote Sensing Agency. The remote sensing program enabled the farmers to exactly provide data on N, P, K, Ca, Mg, Mn, Fe and Cu and variability for the field and in field variability was assessed. It helps farmers to precisely apply the required nutrient in accurate quantities to the root zone during critical phases of crop growth.

Chisel plough

Adoption of chisel plough technology is used once every two years to ensure better aeration to the root zone and efficient drainage during rainy days. Further, it helps the plants develop root systems with characteristic uniformity, pattern, and architecture and in adequate mass.

Hi-Tech Community Nursery for horticultural crops

The hi-tech community coco peat media treated with pseudomonas based seedlings enhances the productivity of high value crops.

Drip and Fertigation System: Drip and fertigation system ensures water savings, precise application of watersoluble fertilizers to root zone and an ideal soil moisture regime of 60 percent and aeration of 40 percent. Apart from these technologies, the adoption of improved seeds, need based plant protection measures and improved weeding practices also plays a very important role in soil conservation in the watershed areas.New agronomic practices like raised bed planting, ridge-furrow method of sowing and sub-surface irrigation offer a vast scope for economizing water use.

This involved not only overcoming the farmer's financial inability to invest in a relatively expensive technology, but also fostering cooperative behavior and improving individual bargaining power through the formation of local farmers associations. This model of extension education had a strong demonstration effect that encouraged the diffusion of critical facts about precision farming.

Conservation and Renovation of water bodies in the watershed areas

The irrigation infrastructure of freshwater irrigation reservoirs, dams, tanks, ponds and a network of canals from rivers, ground water, well based systems, and other rain water harvesting products should be maintained with proper design of irrigation system for reduces water conveyance losses for covering more irrigated area in India. In this context, the Indian government also inculcate new policies and schemes to improve agricultural productivity and increases water use efficiency. One example is the launch of (approx.) ~ USD 7,5 billion "Pradhan Mantri Krishi Sinchai Yojana (PMKSY)". The impact of this scheme can be greatly enhanced, however, by restoring the original flexibility of the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) in asset creation (Surender 2019).

Promotion of practicing conservation agriculture on a large scale for conserving soil moisture, improving soil nutrient status, soil texture, and weeds, among others, water pricing for the agriculture sector and increase in the cost of pumping, salination, presence of heavy metals and strengthening cross-sectoral water governance also support effective water management in the watershed areas.

Extension strategies and methodologies for enhancing adoption of Soil conservation and agronomical technologies in Watersheds

Extension is an applied behavioral science that brings about desirable behavioral changes in farmers standard of living. The philosophy of good extension work is not "What to think and do?" It is about "How to think and do?" for their betterment. Adopting soil conservation and agronomical technologies in watersheds areas not only saves natural resources. It also enhances, agricultural yield and reduces the cost of cultivation. Land, water and vegetation

are the most vital natural resources and provide life supporting systems for human beings and animals. Over-exploitation and improper management of these resources are causing serious threat to environmental degradation in the country. Integrated Watershed Management (IWM) is an approach to the area planning of natural resources, especially, land, water and plants for the socio-economic needs of human society and the community concerned. It involves the exploration and development of the complex relationship between the resources of watershed and the people of the area. Watershed management has to be sustainable on ecosystem from when the treated watershed would permit maximum possible stability through the processes of production, consumption and regeneration on the basis of watershed is being implemented throughout the country. Although watershed has been in existence for long time, they became popular in 1980's when large number of model watersheds under the aegis of National Watershed Programme were launched in the country. Careful implementation of the above mentioned soil conservation technologies by the farmers at the location specific agro ecological perspective ensures resource management on watershed basis for the stabilization of production system for the sustenance of local population.

Important Strategies / Recommendations (Om Prakash, 2004)

1. **Sharing experiences**

The above mentioned soil water conservation technologies practiced by farmers and extension delivery agents and other stakeholders should share the impacts and identify appropriate mechanisms for disseminating such information for larger scale adoption.

2. **Using appropriate participatory processes**

The participatory bottom-up approach and experience sharing of soil conservation technologies support sustainable adoption and replicable activities with the support of all the concerned stakeholders, agencies, organizations, officials and members of the Water shed region.

- **Information and Communication Technology applications** (K. M. Singh. 2015)

The Information and Communication Technologies in various forms starting from, information sharing to social media based group activities, networking and Geographical Information System based services, artificial intelligence, precision farming and remote sensor based technologies plays very important role in sustainable adoption of soil conservation and agronomical technologies in watersheds

3. **Group based Extension Approaches:**

The farming System-based group based public – private partnership led group based organization oriented farmers are doing business and farm machinery, extension advisories and custom hiring services activities. Hence, in this manner also we can also promote soil conservation and agronomical technologies in Watersheds areas (Rasheed Sulaiman V, 2016)

Apart from these advanced extension approaches, the traditional also plays very important role in the of **adoption of soil conservation and agronomical technologies in Watersheds.** The major extension methods practices in agricultural extension are classified under three categories (Marco Ferroni. 2012)

1. Individual Extension Methods
2. Group based Extension Methods
3. Mass media based Extension Methods.

Individual	**Group (20-30 persons)**	**Mass of Media based Community (more than 30 persons)**
Farm & Home visit, personal contact	Small Group Discussion	Bulletins circulations
Letters (Personal)	Panel (2-8 speakers)	Leaflet / booklet / folder / pamphlet
Office call	Lecture	Magazine
Telephone Call	Symposium (2-3 speakers)	News paper
Result demonstration	Result demonstration	Exhibition and Fairs
	Method demonstration	Television
	Tour and field days	Radio
	Innovative farmers meeting	Posters
	Training camp	Agricultural Technology – documentation Film
	Role playing	Circular
	Puppet show	
	Slide Show presentation	
	Farmer Field School	
	Flash cards display	

Apart from these methods, other innovative extension approaches like Participatory Rural Appraisal (PRA), Institute linkage extension programs through Agro-eco system analysis, case study approach, Information and Communication Technologies (ICTs) like expert systems, web based extension and social media based extension play a very important role in the transfer of technology processes in the adoption process of soil conservation and agronomical technologies in watersheds for enhancing agricultural production and sustainable natural resource management perspectives. Further, the watershed farmer's community based conservation and welfare group based association in watershed areas enhances community participation in watershed management. It also facilitates the exchange and transmission of indigenous knowledge. In this context, community-led initiatives that promote the conservation, use, and management of natural resources like soil and water for increased agricultural production, poverty reduction and recognition of socio-economic and environmental aspects for better implementation and adoption of soil conservation and agronomical technologies in watersheds.

Constraints

The major constraints in the adoption of soil conservation and agronomical technologies in watersheds are technological constraints followed by socio-economic, personal and physical, lack of skilled agricultural labour, lack of awareness of agro environmental problems followed by lack of local technical expertise, lack of success stories and demonstrated impacts about the soil conservation practices and unfavorable farmers' attitude & knowledge and perception levels towards the soil conservation practices in the watershed areas.

Suggestions for improving soil conservation practices and their adoption in the watershed regions:

India accounts for about 17% of the world's population but only 4% of the worlds' fresh water resources. Hence, promotion of awareness and recognition of the extension services and publicity in different media about the soil conservation and agronomical technologies through the Farmer Field Schools and Farming System Research and extension strategies. Promotion of skill oriented training programs helps to improve the farmers'confidence. Establishing farmers' discussion groups in every village. Organizing pre-season training on soil conservation and agronomical technologies in watersheds. Promotion of farmer-to-farmer extension through promotion of leadership based farmer cooperation; participatory farmer first approach and farming systems based extension strategy are much required for successful implementation of the eco-friendly conservation practices. Technologies such as conservative agriculture should be popularized, as they known to increase water use efficiency. As FAO (2005) reported, the challenge is for would-be advisers to develop a sense of partnership with farmers, participating with them in defining and solving problems rather than only expecting them to participate in implementing projects prepared from outside. Instead of using a top-down approach where the extension agent places conservation agriculture demonstrations in farmer fields and expects the farmer to adopt, a more participatory system is required where the farmers are enabled through provision of equipment and training to experiment with the technology and find out for themselves whether it works and what fine-tuning is needed to make it successful on their land.

Conclusion

Rain fed agriculture plays an important role in the country's economy. An achievement of food security, at the current nutritional levels, requires an additional 100 million tons (MT) of food grain to be produced or imported by 2050. Presently, India is facing a decrease in available water resources that has implications for India's agriculture sector. At the same time, these soil conservation and agronomical technologies are very effective and easily adoptable by small and marginal farmers in various watersheds starting from arid Rajasthan to moist and hilly north eastern hilly regions. These farmer friendly practices are more efficient than structural rehabilitation measures such as check dams, stone walls, bench terracing and gabions which are considered very effective rehabilitation measures. Hence, the focus on natural resource management extension efforts only needed for sustainable adoption of these technologies. It is possible because of the intensified extension effort to promote soil conservation and agronomical technologies in the watershed areas. Appropriate strategies and programs are to be designed by the extension agencies according to the specific group of farmers. Need based capacity building programs under the watershed based farming system approach are to be organized in order to inculcate knowledge and expertise among the farming community to promote soil conservation practices.Appropriate transfer of technology activities viz., exposure visits, training programmes and advisory services are to be rendered to the stake holders to enhance the empowerment of the farming community leading to considerable adoption of soil conservation and agronomic technologies for efficient soil, water and sustainable ecosystem management processes.

References

Aashish Velkar, Tamil Nadu Precision Farming Project: An Evaluation, Department of Economic History

London School of Economics Houghton Street London WC2A 2AE, 2008.

Ghose AK , B Schimm, S Niyogi - New technology for surface mining in the 21st century–emerging role for surface miners, Journal of Mines Metals and Fuels, 2008

Kakade. B. K, Integrated Watershed Development Programme: Baif Experience

Kakade, B.K and Hegde. N.G. "Integrated Watershed Development: BAIF Approach" a paper in 'Integrated Rural Development for Sustainable Livelihood'.

Marco Ferroni and Yuan Zhou, Achievements and Challenges in Agricultural Extension in India, Global Journal of Emerging Market Economies 4(3) 319–346 © 2012 Emerging Markets Forum SAGE Publications Los Angeles, London, New Delhi, Singapore, Washington DC DOI: 10.1177/0974910112460435 http://eme.sagepub.com

Muralikrishnan.L,H. Philip , V. Ravichandren , M. Chinnathurai and K.Valliappan, Eco–friendly conservation practices in the Nilgiris district of Western ghats – an analysis, unpublished thesis, Department of Agricultural Extension and Rural Sociology, TNAU, Coimbatore, 2015

Muralikrishnan. L., Ram Bahal ,R.N.Padaria, Krishan Lal and AnchalDass. Adoption and Impact of Precision Farming in Tamil Nadu, Unpublished Thesis, Division of Agricultural Extension, ICAR –IARI, New Delhi. 2012

Om Prakash, *Y.V.R. Reddy, G. Sastry, P. Srinivas Rao and H.P. Singh* Impact of Watershed Development Programmes on Adoption of Crop Production Technologies under different AERs of India and Extension strategies for soil and water conservation /Integrated Watershed Management, Central Research Institute for Dryland Agriculture (ICAR), Hyderabad, 2004

Rasheed Sulaiman V. and Magdalena L. Blum, Tailoring rural advisory services for family farms, Food and Agriculture Organization of the United Nations and Global forum for rural advisory services, ISBN 978-92-5-109257-6

SinghK. M, Abhay Kumar, R.K.P. Singh Role of Information and Communication Technologies in Indian Agriculture: An Overview, SSRN Electronic Journal, 10.2139/ssrn.2570710, 2015.

Surender, *Role of Water Resources in Agricultural Development*, Journal of Advances and Scholarly Researches in Allied Education [JASRAE] (Vol:16/ Issue: 6) DOI: 10.29070/JASRAE 2019.

Water erosion appraisal in different Agro ecological regions, Research Achievement in the ANNUAL REPORT OF Central Soil and water conservation research Institute, 2010-11

www. Indiawatertool.in, Water stress Mapping in India, World resources Institute, 2015.

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