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AGRI-Life

Transforming agriculture in Bundelkhand through rainbow revolution............

"Agro-technologies for sustainable development of rainfed and water scarce areas"

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From Vice Chancellor's Desk...

Rainfed areas currently constitute 55 per cent of the net sown area of the country and are home to 60% of livestock and 40 per cent of human population. Even after realizing the full irrigation potential, about 50 per cent of the cultivated area will remain rainfed. Earlier efforts of characterization of rainfed areas mainly focused on a few bio-physical indicators without giving importance to socio-economic aspects related to livelihoods issues. In order to meet this challenge, little focus have been given to prioritize the rainfed areas with respect to the sustainability, resource allocation and targeting of interventions based on resource availability, livelihood parameters and potential for development.

World population roughly doubled over the last 50 years, while water consumption worldwide quadrupled. With urban populations growing faster than rural populations, the financial pressures on urban water utilities is intensifying. Dry lands are regions of water scarcity. However, these dry lands have high mean temperatures and often prolonged dry seasons leading to high rates of water loss to evaporation and transpiration. Dry land ecosystems and their biodiversity are uniquely adapted to these twin features of water scarcity and climatic variability. Dryland species show many remarkable adaptations to water stress, including the ability to conserve water, to extract water efficiently when it is scarce, or to survive periods without water.

In order to promote some scaling up techniques in conservation of water resources and to enhance rainfed farming techniques by creating awareness in the areas of arid and semi arid across country. There is widespread concern that poor water management will be one of the major factors limiting sustainable development during the next few decades. Water shortages are common in many regions, and are exacerbated by the pollution or degradation of many water bodies. There are conflicting demands for available water resources, both between human, economic, and ecosystem needs and between regions sharing a single water basin, in some cases leading to geopolitical security threats. The business as usual approach of taking major interventions uniformly across all the regions of the country has not paid much dividend. Therefore, regionally differentiated interventions befitting natural resource endowment, social capital, infrastructure and economic conditions are need of the hour to meet the local challenges and enhance livelihoods.

This issue of Agri-Life with the theme "Agrotechnologies for Sustainable Development of Rainfed and Water Scarce Areas" deals with the scientific and empirical studies on various updated techniques in mitigating the scarce water resources which should be focused as need of hour basis. It is expected that the studies published here will enhance the awareness and techniques of rainfed agriculture towards the effective utilization of ground water and conservation of natural resources.

Lastly, I congratulate Prof Anil Kumar, and other members of editorial board for their efforts in bringing out this valuable publication. This will take a lead in promoting the importance of water resources to a greater extent in the country. I hope the publication will be read and used widely across our country.

(Arvind Kumar)
Vice Chancellor

Editorial

"Agro-technologies for sustainable development of rainfed and water scarce areas"

Rainfed agriculture produces much of the food as consumed globally and by poor communities in developing countries. Most countries in the world depend primarily on it for their grain food production. In India it is practiced in more than 50 per cent net cultivated area, which makes rank of India first in cultivation of 86 Mha areas under rainfed agriculture globally as well as value of the produce. Its contributes 44% of rice, 87% of coarse cereals like sorghum, pearl millet, maize, nearly 85% of food legumes, 72% of oilseeds, 65% of cotton and 90% of minor millets contributing nearly to 40% of national food basket while supporting more than 60% livestock population of the country, therefore has a critical role in the country's economy.

Dry lands are also characterized by extremely high levels of climatic uncertainty; in many dry lands annual precipitation can be 50% above or below the mean in the majority of years. Land is often degraded, crops frequently die because of drought or floods and few methods are in place for managing water more effectively. It is this loss of water that determines their aridity and drought. Soils often have inadequate amounts of essential nutrients, organic matter and ecosystems have lost a portion of their inherent biodiversity. In most of these areas, increasing populations have placed substantial pressure on rainfed cropland and on the land and water resources used by livestock. Some plants and animals are highly resistant to the stress of drought, some are experts in water storage or water harvesting whilst others lie dormant through long dry spells, or move to find water elsewhere.

Climate change will likely exacerbate this trend, as increasing temperatures will bring drier conditions and shorter, more intense rainfall events. Reducing the vulnerability of dry land communities to climate change will require measures that diversify livelihood options, reduce pressure on natural resources, and restore and protect dry land ecosystems through sustainable management practices. Though many farmers in rainfed areas capture and store water for use as supplemental irrigation, millions more are entirely dependent on rainfall. A great number of poor families in these countries still face poverty, hunger, food insecurity and malnutrition. We need to better understand the risks and trade-offs that household's face in rainfed settings. The inherent uncertainty and extensive poverty that characterize rainfed systems generate research questions that are quite different from those pertaining to irrigated agriculture.

Water productivity is the amount of crop produced per drop of water, which tends to be low in rain-fed farming systems, while losses from evaporation are high. With improved land and water management practices as well as a more secure environmental and socio-economic asset base, communities were able to cope with climate stresses, establishing a solid foundation upon which to base climate change adaptation strategies. We must also deepen our understanding of how livestock production in association with water scarce environments can be improved. The prevailing knowledge focuses on double yields in rainfed agriculture, even where water implies a particular challenge instead focus should be on raising farm income and not just the crop production of dry land agriculture by emphasising cultivation of high value food crops such as oilseeds and pulses, besides the traditional cash crops and promoting alternative uses of dry crops including through processing.

The effective utilization of water resources urges a need based approach for attaining the objectives of sustainable development goals. Further, technological interventions and improved agricultural packages in solving such recalcitrant problems of rainfed agriculture is the need of time. There are many reasons why such attempts for enhancing soil and water management are not pro-actively undertaken at institutions for improving livelihood, social, economic development. I hope this issue of Agri-Life with the theme "Agrotechnologies for Sustainable Development of Rainfed and Water Scarce Areas" will be referred thoroughly at different quarters.

(Anil Kumar)
Editor-in-Chief

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Dryland agriculture: An agrotechnology for water scarce areas

Gayatri Kumawat[1], Kailash Chandra[1], Chander Kanta Kumawat[2] and Subhash Chand[3]

India occupies about 60% area under dryland agriculture and contributes about 40% in Indian economy. Dryland agriculture primarily depends upon rainfall and is needed to meet food and feed demand of burgeoning human and livestock population in the country. The crop production can be increased by crop and varietal diversification, application of anti-transpirants, and effective use of agronomic practices in dryland agriculture.

Dryland agriculture refers to growing of agricultural crops solely under natural rainfall conditions without irrigation. The area under dryland agriculture in India is about 60%, whereas it encompasses about 40% contribution to Indian economy. The rainfall is the prima-facie which decides the time of sowing in dry land areas. Dryland agriculture provides livelihood for about 40% of the rural population and feed security for 60% of the cattle population, worldwide. Major dry farming crops are millets such as sorghum, pearl millet and ragi, oilseeds like mustard and rapeseed and pulse crops like pigeon pea, gram and lentil. Almost 80% of maize and sorghum, 90% of pearl millet, 70% of cotton and 95% of pulses and 75% of oilseeds are obtained from dry-land agriculture in India. Annually, drought alone reduces nearly 15% yield potential of food grains. In Indian subcontinent, nearly 84 districts and about 33% of wheat and 66% of rice crops are under rainfed condition. Rajasthan comes first in total dry land area followed by Karnataka and Bundelkhand region of Uttar Pradesh and Madhya Pradesh.

Rainfed farming and dryland farming both exclude irrigation, but beyond that, they can differ significantly. Dryland farming is a special case of rainfed agriculture practiced in arid and semiarid regions in which annual precipitation is about 20–35% of potential evapotranspiration. The conditions of moderate to severe moisture stress occur during a substantial part of the year, greatly limiting yield potential and in which farming emphasizes water conservation in all practices throughout the year. Rainfed systems, although they include dryland systems, can also include systems which emphasize disposal of excess water, maximum crop yields and high inputs of fertilizer.

Based on the amount of rainfall received, dryland agriculture can be grouped into following three categories:-

1. Dry farming- Cultivation of crops in areas where average rainfall is less than 750 mm per annum, acute shortage of moisture in soil, less than 75 days crop growing season and single crop for intercropping system adopted. Dry farming is adopted in arid regions where dry spells occur most commonly and crop failure is more frequent.

2. Dryland farming- Cultivation of crops in areas which receive rainfall from 750 to 1150 mm per annum, shortage of moisture, 75 to 120 days crop growing season, single crop for intercropping system adopted. Dryland farming is adopted in semi-arid regions where dry spell and crop failure occur less frequently.

3. Rainfed farming- Cultivation of crops in areas which receive more than 1150 mm per annum, enough moisture, more than 120 days crop growing season, single crop or multi cropping system adopted. Rainfed farming is adopted in humid regions where dry spell absence and crop failure rarely occur.

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[2]*JAU, Junagadh*
[3]*ICAR-IGFRI, Jhansi*

Aberrant weather condition in dryland areas and their management

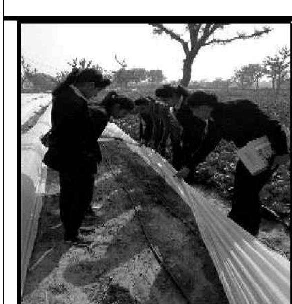
1. **Inadequate and uneven distribution of rainfall-** Predominantly, rainfall is low and highly variable pattern which results in uncertain crop yield or even total crop failure. Besides its uncertainty, the distribution of rainfall during the crop period is erratic and uneven, receiving high amounts of rain, when it is not needed. Cultivate low water requiring crops such as bajra and sorghum, grow short duration crops, conserve water, and life-saving irrigation are adopted for this situation.
2. **Long gap of rainfall**: To compensate this gap increase the required seed rate, spraying the urea solution, providing life saving irrigation, weeding and intercultural operations.
3. **Early onset of monsoon**: Cultivate pearl millet, sesame etc. crop.
4. **Late onset of monsoon-** Due to late onset of monsoon, the sowing of crops is delayed resulting in poor yields due to less time period from sowing to crop maturity. Under these circumstances, alternate crops such as castor, green gram, cowpea and sunflower can be sown being their short life span. Most suitable crop for these conditions is sunflower. Dry sowing, seed soaking and treatment, complete weed control adopted for improved yield.
5. **Early cessation of rains/Early withdrawal of rainfall-** For this situation select short duration crop varieties, mulching, life-saving irrigation and decreases the plant population.

Use of Anti-transpirants in dryland farming:

Anti-transpirants are compounds applied to the leaves of plants to reduce transpiration. Following anti-transpirants used in dry land farming-

- **Stomatal closure type:** MA (Phenyl Mercuric Acetate) and Potassium metabisulphate. Earlier 2, 4-D and Atrazine also used as anti-transpirants as stomatal closure type. However, as per Ministry of Agriculture and Farmers Welfare (Department of Agriculture, Co-operation and Farmer' Welfare) Notification New Delhi, the 14th May, 2020, but now they are banned.
- **Film forming type** Thin film forming (Cetyl-alcohol), thick film forming (waxol, S-800 and silicon)
- **Reflectant type** Kaoline, china clay, Ca-bicarbonate and lime water

Dryland farming extensively covers major crop area of Indian subcontinent and yield losses can be minimized by applying soil conditioners and amendments, wind reduction strategies such as wind breaks, shelterbelts, strip cultivation, and cultivation techniques like-terracing, contour ploughing, strip cropping, and crop rotation and intercropping, re-growth of trees and soil rebuilding.

Dryland techniques to reduce evaporation			
Mulching	Anti-transpirants	Windbreaks/ Shelterbelts	Weed control
			

Breeding drought tolerant wheat varieties for rainfed agriculture

Shashikumara P, Prabha Singh, Parichita Priyadarshini, Brijesh Mehta and Anup Kumar

Wheat being one of the major cereal crops grown worldwide in terms of area and world production, out of this nearly 50% of the world wheat growing area is affected by drought stress. Genetic variation for drought tolerance exists in wheat cultivars and improved adaptation response in wheat can be achieved by implementing appropriate crossing and selection strategies.

Drought critically affects wheat (*Triticum aestivum* L) crop growth and productivity, causing decrease in yield by 27.5%. Wheat being one of the major cereal crops grown worldwide in an area of 218.54 million hectare with a world production of 771.71 million tons. But, nearly 50% of the world wheat growing area (230 million hectares) is affected by drought stress. In India, wheat is cultivated in an area of 30.23 million ha, with annual production of 101.3 million tonnes. It has been predicted that for every rise in 1°C of global warming leads to a decrease of 4.0 to 6.5% of wheat production. Nearly 80% of wheat growing area is under irrigation in India, but two third areas receive partial irrigations from the recommended six irrigation. In the future, water will be the main scarcity for wheat production.

Available wheat varieties for drought tolerance: Present wheat varieties are mainly bred for irrigated conditions. They fail to reach expected genetic potential under restricted irrigation and rainfed environment. Some varieties have been released for rainfed conditions are *viz.*, C306, HD2987, HI1500 and HD2888. The productivity of these varieties is very low. There is a need for greater attention to develop drought tolerant, climate resilient varieties for a rainfed environment.

How to improve drought tolerance?

Breeding approaches by understanding the physio-biochemical responses: Genetic variation for drought tolerance exists in wheat cultivars and improved adaptation response in wheat can be achieved by implementing appropriate crossing and selection strategies. Earlier studies suggest that physiological traits associated with yield under drought have the potential to increase selection efficiency . A comprehensive understanding of the genetics of physiological traits and precise selection methods could enable the development of drought-tolerant cultivars. As drought tolerance is conditioned by multicomponent responses that vary in the intensity and duration. Productivity of wheat under drought condition strongly associated with physiological features such as leaf characters (low canopy temperature, stay green, chlorophyll content, early ground cover, normalized difference vegetative difference etc.) water use efficiency and yield component traits (thousand grain weight, spike length, grain number per spike etc.). integrating physiological traits associated with yield under moisture stress have potential to improve production. The difficulty in phenotyping physiological traits in large population can overcome by using normalized difference vegetative index (NDVI), canopy temperature (CT), relative water content (RWC) chlorophyll content by SPAD chlorophyll meter reading, carbon isotope discrimination, IRGA, Chlorophyll fluorescence using fluorometer, Stomatal conductance using Porometer and early ground cover as they are robust and have high potential in screening the genotypes under moisture stress condition. However, conventionally combining multicomponent drought tolerance associated traits into a single cultivar using

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traditional breeding strategies is very difficult. Hence deciphering the genomic regions underlying drought tolerance traits using molecular markers techniques like QTL mapping, association mapping can overcome these limitations. Achieving higher grain yield (GY) under water limited condition is a big task since it is a complex trait affected by many component traits such as, thousand grain weight (TGW), grain weight per spike (GWPS) and harvest index (HI). Thus, improvement for yield component traits could be more effective than direct targeting for grain yield itself. The positive combination of physiological and yield component traits in a genotype certainly increases the GY under moisture deficit stress condition. Many attempts have been made to map genomic regions for plant height (PH), coleoptile length (CL), TGW, GY and GWPS. The parallel studies on deciphering genomic regions for various physiological traits and yield component traits serve as robust sources for breeding superior drought tolerant varieties in wheat.

Molecular approach: When genomic regions for drought tolerance traits have been identified, these can be employed in breeding programmes through marker assisted selection. Majorly marker assisted backcross breeding (MABB), marker assisted recurrent selection (MARS) are molecular breeding strategies followed to develop drought tolerant varieties for rainfed environment. Farmers always prefer the dominant varieties they are growing, their acceptance will be more if they get improved versions of their varieties. Variety preference comes not only from their productivity, its takes consideration like disease resistance, grain color, chapathi making quality and price in the market. MABB is the best breeding tool for introgression of drought tolerance traits using molecular markers ie (foreground selection) and maximum recovery of recurrent parent genome (background selection) within one or two backcrosses. This approach has high genetic gain, with improved precision in selection and saving time and cost. Presently, drought tolerant improved versions of varieties like HD2733, GW322, HUW234, HUW468, K307 and DBW17 have been developed. These improved varieties are similar to their original parent with QTL regions associated with drought tolerance being introgressed. They showed higher grain yield under rainfed conditions compared to recurrent parents. such varieties can play an important role in improving productivity under rainfed conditions in wheat growing areas. MARS is another approach where upto 10 to 20 QTL regions will be introgressed following markers assisted selection with intermating of selected lines. This approach has greater impact as it includes minor QTLs. MARS has been successfully executed at IARI, New Delhi, using parents HI1500 and DBW43.

Breeding wheat varieties for abiotic stress tolerance was dependent on conventional screening approaches. However, in the present day, abundant genomic approaches are available to breeders to adapt to the demands of specific target species and breeding objectives. A judicious combination of high-throughput phenotyping with modern genomics will lead to the development of stress tolerant cultivars that will enhance the total food security. The novel molecular breeding selection strategies such as marker assisted backcross breeding and marker assisted recurrent selection has enabled the development of stress tolerant varieties.

> When the Nobel Peace Prize Committee designated me the recipient of the 1970 award for my contribution to the 'green revolution,' they were in effect, I believe, selecting an individual to symbolize the vital role of agriculture and food production in a world that is hungry, both for bread and for peace.
>
> *- Norman Borlaug*

Agro technologies for sustainable development of rainfed and water scarce areas

Sanjay. H.B., Harish J., K. Praneeth and Raj Prasanna

Utilising present practices and technology our farmers are being able to produce 281.37 mt food grains. Out of which 114 mt of food grains are produced through rainfed agriculture, which feeds 44% of Indian population. Some types of crops like nutricereals, pulses and oilseeds are grown majorly through rainfed conditions, still agricultural scientists have huge scope to invent new agro technologies for increasing food production.

Agriculture is the primary source of livelihood in India, about 54.6% of India's population engaged in agriculture and allied activities, which accounts 17.1% of the country's gross value added for 2017-18. India's total geographical area is 328.7 m ha, out of which 140. 1 m ha is reported as Net sown area and 198.4 m ha is the gross cultivated area. Out of 198.4 m ha 115 m ha area is gross rainfed area, which is about 60% of gross cultivated area and 83.4 m ha is gross irrigated area, it accounts only 40% of gross cultivated area. India stands first place among the rainfed agricultural countries of the world in terms of both extend and value of produce. Population of India is increased in geometric progression,in order to meet food security, productivity and production of the food grains should be elevated than the present production of 284.83 mt. But for increasing productivity the main constraint is lack of irrigation facility,it becoming a challenge for the government, Agricultural scientists and farmers to increase the production at water scarce conditions. New practice and technology should be sustainable so that it should not hamper the existing natural resources and it should be available for future generations also. It is reported that 42.64 mt of nutricereals, 31.50 mt of oil seeds and 24.02 mt of pulses are produced in 2018. Among them most of are grown in rainfed farming. By looking above statistics, it is possible to increase India's food production through application of newly developed technologies and consecutively farmers' income can be doubled at the time of 2022.

Strategies for sustained food production in rainfed region:

Rainwater, land and crop management are prerequisites for improved crop production in rainfed farming. Our national food production can be increased by increasing the productivity of crops in rainfed areas and this increased productivity can be achieved by practicing the strategies which are discussed below.

1. Soil and rain water conservation techniques:

For successful dryland farming, efficient conservation of rain water and soil is very essential. Construction of contour bunds, graded bunds, grassy waterways are essential to prevent the excess runoff water. And construction of these structures depend on rainfall intensity, texture of the soil and slope of the land. Application of proper watershed technologies like construction of farm ponds, rainwater harvesting, convey the excess runoff water to form ponds. Prevention of excess evapotranspiration by mulching, intercropping and mixed cropping is mandatory.

Bore well recharge: It is the concept of underground recharge by allowing excessive run of water to the aquifers, so that water source in the underground is maintained for several years.

2. Timely sowing of crops and tillage practices:

Maintenance of proper soil moisture is necessary for good germination and proper crop stand establishment. This can be achieved by practicing proper tillage practices. Medium and shallow tillage

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is practiced for dust mulching, incorporation of FYM and phosphate fertilizers. Deep tillage is beneficial under alluvial and red soil for increasing water intake and holding capacity. Use of seed cum fertilizer drillers plays a vital role in rainfed farming, as it maintains proper distance between seed and fertilizer placement and looks after soil cover over seeds and places the seeds and fertilizer at moisture zone so that proper germination and good crop establishment can be observed.

Timely sowing of crops helps in drought mitigation and it helps in escaping pest, diseases and drought incidence.

Exterminal drought can be managed by early sowing and using short duration varieties.

GPU-48 is a short duration ragi variety, which completes its cropping period in 95-100 days.

3. Adaptation of improved varieties:

Use of drought resistant crop varieties gives a stable production in rainfed farming. Farmers should be aware of the use of drought resistant high yielding varieties. And use of hybrids in rainfed farming is not profitable, as it requires high nutrient and input supply for crop production and is not responsive at low water availability.

4. Use of efficient crop and cropping system:

Climate resilient crops like nutricereals are most suitable for rainfed farming. About 300 mm annual rainfall is sufficient for them to get good yield. Moisture at germination and one or two life saving irrigation or rainfall at seed setting is sufficient to reap good yield.

Based on application of rainwater harvesting technology, soil depth, rainfall pattern, large rainfed areas can be put under intensive cropping system. That is, if annual rainfall is 750 mm with more than 30 weeks of effective growing season then double cropping can be effectively made.

Implementation of mixed and intercropping system:

In a rainfed area where annual rainfall is 500 to 700 mm mixed and intercropping should be employed to get higher returns to the farmers. Intercropping of cereals with legumes help in maintaining soil fertility, prevent moisture evaporation, helps in weed control, and effective land use can be made thereby legume supplement the yield of cereals.

Example: sorghum + red gram, Pearl millet + Black gram, Maize + Soybean, Ragi + Red gram (8:1).

The rainfed area receiving more than 800 mm rainfall can effectively be used for sequence cropping. In Bundelkhand region of Madhya Pradesh rice-wheat, rice-chickpea, Sorghum-chickpea, green gram- wheat sequence cropping is carried out.

5. Integrated approach of nutrient management:

Rainfed farming not only suffers from water scarcity, but also suffers from nutrient deficiency. And hence integrated approach of nutrient management is necessary. Intercropping of legumes with cereal crops gives 20 kg of N per hectare, and providing green manure like Gliricidia leucaena, Sesbania, Dhaincha fulfill 50% of nutrient requirement. Incorporation of FYM and biofertilizers and biocontrol agents like azospirillum, azotobacter, trichoderma, and pseudomonas with soil helps in maintaining good soil health. Recommended dosage of inorganic fertilizer should be applied at the time of sowing with the help of seed cum fertilizer drill helps in correct placement of fertilizer and prevent nutrient losses and increases nutrients use efficiency.

6. Alternate land use system:

Due to current weather conditions, rainfed farming suffers from instability in production and farm income. To provide stability in the farm income alternate land use system and use of marginal land for production of fuel wood, fodder and fibre should be implemented. For this integrating annual crops with perennial components in order to utilise the off seasonal rainfall. This includes, agri-silviculture, silvi-pasture, agri-horticulture, alley cropping etc. By using these livestock like sheep and goat rearing can be practiced which supplement the farm income.

7. Agronomic practices for rainfed farming:

Practicing the seed hardening process before sowing will help in good germination and proper crop establishment and gives resistance to crop against drought. Process of seed hardening can be done by soaking the seeds in water for 12 hours followed by sun drying for 1 day then they are subjected for seed treatment and sowing.

Mulching should be done after sowing helps to prevent evaporation and weeds. Intercropping of legumes with cereals act as mulching material. Shallow ploughing with cultivator while sowing acts as dust mulching prevents excessive water loss from soil.

8. Drought management:

Drought can be defined based on meteorological, agricultural and hydrological criteria. When average seasonal rainfall in a region is less than 75% of the normal is called meteorological drought. If extended dry periods result in insufficient moisture in the root zone of soil causing adverse effects on crops such drought is known as agricultural drought. Hydrological drought is an extended dry period leading to substantial depletion of water sources.

Alternate crops for different periods of sowing that match the delay in sowing have been recommended to mitigate the effect of drought. Creating soil mulches, and minimizing weed population reduce evaporative losses, which extend the life of standing crops under drought. Mitigation of Agricultural drought is possible to some extent through alternate crop strategy, reduction in evaporative losses and better crop husbandry. Harvesting and storage of more rainwater in situ and in tanks can help in mitigation of droughts. Life saving irrigation from stored water under drought conditions can save rainfed crops.

In India about 60% of cultivated land comes under rainfed farming and Indians production can be increased by increasing the productivity of the rainfed area. This can be achieved by proper drought management practices, agronomic practices, rainwater harvesting, prevention of excess run off water, borewell recharge, proper watershed management, use of climate resilient crops like millets or nutricereals, integrated nutrient management and integrated farming system. By proper application of these technologies helps in minimizing the constraints of rainfed farming.

"When tillage begins, other arts follow. The farmers, therefore, are the founders of human civilization."

- Daniel Webste

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A fertile soil alone does not carry agriculture to perfection.

- Elias Hasket Derby

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Agriculture is at the core of the state.

- Dave Cook

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Agriculture is the process of turning eco-systems into people.

- Toby Hemenwayr

Agroforestry for water scarce Bundelkhand region of central India

R.K. Tiwari, Naresh Kumar and Asha Ram

Various agro-techniques are in vogue to manage the tree-crop systems for minimizing the adverse effects of trees on crops. The trees can be accommodated in various fashion to harness bounty of available resources such as light, moisture in order to reap the benefits from both components. In addition to above agroforestry systems in water scarce areas, there could be many more systems depending upon resource availability and demand.

Water is a key to biomass production, as the areas even with high rainfall also suffer from water scarcity beyond or prior to the rainy season. Enhancing biomass productivity in such areas is a challenge as water scarcity limits the growing period. Agroforestry can be a viable option in such areas as tree roots penetrate deeper in soil and extract moisture from deeper layers of the soil. There are many trees which are compatible with crops and grown on croplands. Some of the systems have been discussed here for water scarce regions.

Hedge row plantation: In this system trees are planted at close spacing within the rows. Rows are oriented across the slope spaced 8-10 m apart. This hedgerow is regularly headed back at a height of 1.5-2.5 m. It acts as a barrier against run-off and soil loss and fetches fuel and fodder. Species like Subabul, Mulberry, Arjun etc. are well suited for hedge row plantation. Hedge rows offer shelter and act as wind break for crops grown in inter row spaces. They specially suit well for vegetable cultivation during summer months. They help in creating diversification besides ecosystem services and offer alternate livelihood support opportunities. In water scarce regions like Jhansi, Arjun hedge row provides opportunity for silkworm rearing. Similarly, Subabul hedge row is considered good for animal fodder and fuelwood. The hedgerow species manage to grow with the water provided to the companion crop, hence, do not require separate watering which is a scarce commodity. Thus, with available resources biomass productivity can be increased.

Boundary plantation: Many places in the country have undergone land consolidation. Mechanical bunds are there to demarcate boundaries. Quite often farmers plant trees/shrubs and grasses on boundary, besides demarcation, they act as live fences and wind breaks. In addition, they also yield biomass. Normally, tall trees of long gestation period are planted at 10-15 m spacing. In water scarce areas, it could be Teak, Shisham, Ardu, Neem, Babul etc. In between tall trees medium growing trees like Sarifa, Jungle jalebi, Kaith etc. are planted. Further, live fence species like Karonda, Ber, Kumat, Mehdi etc. are planted to make the boundary impermeable for stray cattle or miscreants. It is advisable to plant three species in 3 rows in a chess board pattern. Bamboo is another plant well suited for boundary plantation. Bamboo is highly economical as well and has multiple uses.

Bund plantation: Bund plantation is the most common agroforestry system throughout the country. In water scarce regions, Neem, Chiraunjee, Babul, Shisham, Reonjha, Ber are commonly planted. Quite often these are naturally regenerated plants which are well taken care of by farmers. Recently, teak is in high demand by farmers due to its high market price. Narrow canopy, non browsable nature and high commercial value render the species fit for bund plantation. Bund plantation need to be regulated by systematic plantation of economical species like Aonla, Bael, Sharifa, Ber and timber species like Teak, Malabar neem, Subabul and

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fodder species like Ardu, Agasthi, Gliricidia etc. However, farmers should ensure quality planting material of known variety or strain for higher productivity. Tending of plants on field bunds should be attended to reduce the losses of crop yield due to tree shade. Even hedge plantations on bunds need to be encouraged and maintained under coppice management. Semi perennial fodder grasses like NBH, Guinea grass or Napier and other economical grasses like *Saccharum munja, Cymbopogon citratus*, *Palma rosa* etc. can be planted for economic gains besides ecosystem services.

Agri-horticulture plantations: Agri-horticulture land use is preferred by the farmers as fruits have local markets throughout the country. In water scarce areas fruits like Sharifa, Ber, Bael, Aonla, Guava are planted with crops or vegetables including spices. Trees are planted in a rectangular system at 50% density of normal plantation *i.e.* row spacing is doubled while plant to plant spacing is kept as normal orchard spacing. Fruit trees start commercial bearing from 5^{th} year onwards and give regular income. Tree biomass in the agri-horticulture system is a bonus. During the pre-bearing phase of trees, prevalent crops of the region are grown while shade loving crops are preferred once trees develop their huge canopy and begin to impact crop yield due to shade. In the agri-horticulture system orientation of tree rows plays a very important role. Tree rows should be oriented in the E-W direction to minimize shade effect on companion crops. Training of plants is an important operation of the agri-horticulture system. Trees should be trained as single stem up to a height of 1.5 m to facilitate machine operation in the field. Further, scaffold branches should be encouraged in E-W direction only. Pruning of trees is done as per requirement of the species. However, time of pruning is adjusted to suit the crop.

Agri-silviculture plantation : Agri-silviculture system refers to growing of forest trees with crops. In this system trees are planted at desired spacing preferably in a rectangular system. Trees are pruned from 2^{nd} or 3^{rd} year so that the main trunk gains proper strength to support the canopy. In case of timber trees, they are lopped up to 75% of their height. Straight bole, free from knots is a major consideration in case of timber and industrial wood. Teak, Gamhar, Malabar neem are some of the important tree species for water scarce regions. Bamboo, Ardu and Kadamba are other hardy species which can be grown under the agri-silviculture system. As for as possible plantation should be done during early monsoon season to ensure survival of plants during 1^{st} summer season. Rain water harvesting and storage should be ensured to facilitate life-saving irrigation.

Silvipasture : Silvipasture land use is best suited for non-arable lands. In fact, there can't be any better land use in non-arable lands other than silvipasture. As name suggests, trees are planted in pasture lands. There could be timber trees, fodder trees which can produce to feed during scarcity period. Thus, trees in wasteland ensure sustainability in fodder availability. In drought prone areas, they could be Bamboo, Subabul, Black siris, Ber or other browsable tee species. Besides production, trees in non-arable lands offer protection against erosion and build fertility. In water scarce areas of Bundelkhand, 10 t/ha/year biomass production has been reported from established silvipasture system as compared to control where biomass production was even less than 1 t/ha/year. If well planned, silvipasture system can sustain 10 sheep or goat along with their offspring throughout the year without any supplementation from outside. Silvipasture land use is, also, crucial for regulating runoff and water courses in non-arable lands which are often main source of siltation of water bodies. Biodiversity of silvipasture system is high and provides shelter, food for different types of fauna.

Homestead: Homestead plantations constitute an integral part of agroforestry land use. They are highly diverse and meet multiple requirements of farmers such as fruits, vegetables, spices, fodder, timber and recreation or aesthetic values. Every household in rural areas has some vacant land around their house, where they grow fruit plants, vegetables, flowers etc. Homestead plantations are better taken care of due to the presence of people, they are well protected and watered even in water scarce areas. Plantation of

Neem, Jackfruit, seasonal vegetables, spices etc. meet various needs of farmers. In coastal India, homestead plantations are very prominent.

Shelter belts and Wind breaks : Shelter belts and wind breaks are specialized forms of agroforestry in desert areas where relative humidity is very low and hot desiccating winds are common. These shelterbelts and windbreaks reduce impact of wind, check wind erosion and moderate microclimate to facilitate cropping in leeward direction. Shelter belts/wind breaks are planted in 3 rows, outer row of tall trees, middle row of medium size trees and shrubs and inner row of thorny bushes or grasses. Thus, they check wind up to 3 times the height of trees. Usually they are long tree belts and oriented across the most common wind direction. At small scale, hedgerows do the same job. This can be practically observed in river bank cultivation during summers. Live barriers of *Saccharum munja*, vetiver offer protection to summer vegetable crops on the river side.

Aqua - agroforestry which includes plantation of trees along/around water bodies, fish farming, water chestnut, lotus etc. in ponds protected with thick vegetation is another example of agroforestry. Similarly, sericulture on tree leaves, bee-keeping with ornamental plants are other prominent agroforestry systems for such regions. Avenue plantation, roadside plantation, parks with trees and grasses are other important agroforestry systems of water scarce regions.

Thus, agroforestry in water scarce regions not only ensures high biomass production but also diversifies the produce. It provides more income and protects the environment, checks degradation and increases aesthetic beauty. The system warrants careful selection of components for higher productivity, profitability, diversity and employment in water scarce regions.

Agriculture is a fundamental source of national prosperity.

- J. J. Mapes

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If agriculture goes wrong, nothing else will have a chance to go right in the country.

- M. S. Swaminathan

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Agriculture is our wisest pursuit, because it will in the end contribute most to real wealth, good morals, and happiness.

- Thomas Jefferson

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The discovery of agriculture was the first big step toward a civilized life.

- Arthur Keith

Effective utilization of degraded soil and undulating lands of Chambal ravines: Possibilities & opportunities

Gaurav Sharma[1], Amita Sharma[2], M.J. Dobriyal[1] and Vishnu Kumar[1]

The Chambal ravines are unique in that they are deep to very deep and are devoid of vegetation. Madhya Pradesh alone has a large area of these ravines of which nearly 80% are in Chambal Division. Promoting commercial cultivation through land levelling of ravines is not a feasible and viable option. Integrated approach of using gullies per land capability classes, soil and water conservation measures and putting land under permanent vegetation cover involving horticulture, agroforestry and pastures is required for efficient utilization of the degraded soil and undulating topography. Use and promotion of indigenous available trees/shrubs/herbs suitable for degraded soil and adapted to the climatic conditions of Chambal region is one of the important interventions apart from the possibilities of utilizing ravines for establishing defence production units/ industrial corridors and non-conventional energy generation.

The states of Madhya Pradesh, Uttar Pradesh, Rajasthan and Gujarat account for 2.7 million hectares, or 70 per cent, of the country's ravines. Studies in ravine formation have revealed that its expansion is at 9.5 per cent per annum and the rate of soil loss is 65 tonne per hectare per year. Thus, every year nearly 8,000 hectares of land is claimed by ravines. The NCA (1976) had put ravine reclamation on national priority. The ravines occur along the river Yamuna, Ken, Gomati and Kholas in Uttar Pradesh and along the river Chambal, Essen, Kalishindh, Betwa and Kshipra in Madhya Pradesh covering majorly the Chambal division of MP and ravine areas in different parts of Bundelkhand *viz.*, Orai, Banda and Datia. Among various categories of wastelands, the Chambal Ravines, formed as a result of severe water erosion, stretching across three states of M.P., Rajasthan and U.P are perhaps one of the worst physically degraded forms of once highly fertile cultivated lands. These are totally unproductive vulnerable ecosystems in existence with several on and off-site implications. The Chambal ravines are unique in that they are deep to very deep having 20 to more than 60 m depth and are devoid of vegetation. Out of the total ravines in Madhya Pradesh, Chambal division with Bhind, Morena and Sheopur districts accounts for 80% alone. These ravines are spreading at a rate of 2.20 ha per day.

However, there is a scope of utilizing these vast area of Chambal ravines available in the three states for use either at no cost (the government owned) or at very low cost (owned by the farmers) compared to the precious and costly agricultural land. Rehabilitation of ravine lands involves treatment of table and marginal lands contributing runoff to the gullies and should also be of economic utilization of gullied ravines apart from being feasible from adaptation point of view. It requires an integrated approach of using gullies per land capability classes, soil and water conservation measures and putting land under permanent vegetation cover involving afforestation, agroforestry, horticulture and pastures.

Opportunities:

Despite several repeated failures in the past to properly utilize the degraded ravines soil, there are opportunities and possibilities to effectively utilize the degraded soils and undulating lands of the ravines through the following interventions:

Greening the ravines with mixed vegetation:

Fast growing herbaceous plants, grasses, shrubs, trees which are easy to establish, and have fibrous roots can be grown ravine lands. Mixed seeds of Ficus spps including *Ficus carica*, sweet orange, mandarin, lime, kinnow, appleber, karanj, drumstick, castor, neem, *Prosopis cinereria*, adusha, and several

[1]*RLBCAU, Jhansi, UP*
[2]*RVSKVV, Gwalior, MP*

other native vegetation be enclosed (pelletized) in the form of bricks (not balls because they will roll down) made of Vermicompost or FYM or any other suitable material like nutrient mixed charcoal dust to protect from birds and other extreme weather conditions like temperature. These can be aerially seeded by drones etc and wherever possible may be planted manually, before the rainy season. When the rain arrives, the seeds will germinate and establish themselves. Also, to check degrading lands along ravine areas plantation of bamboo and/or suitable grasses/forage may be done for the arresting process of gully head extension.

Utilizing ravines for establishing defence production units/ industrial corridors:

The ravines, having rivers as water source and rail as well as road connectivity, could be utilized for establishing defence production units /defence establishment/ industrial corridors with proper effluent treatment plants. Much of the ravine land belongs to the government and some is owned by the farmers. The cost of compensation to be paid to the farmers and the social impact assessment (SIA), if any, will be much lower than that for agricultural land. The amount so saved on compensation could be utilized for infrastructure development. However, it may be at the cost of other environmental and social factors.

Promoting organic farming in pockets:

Organic farming may be promoted in those areas which are already following it by default. This may check the further spreading of the deteriorated soil. Priority needs to be given to fruits, vegetables, spices, medicinal and aromatic plants and pulses and oilseeds cultivation. In rainfed uplands, on-farm available resource based low input technology and its blending with traditional wisdom of farmers may be encouraged through incentives for its easy adoption and shifting away from chemical farming wherever being done.

Non-conventional energy generation:

Installing solar panels and windmills for non-conventional energy generation is another option to utilize the ravine land. The areas having rocky soil not suitable for agriculture/horticulture/agroforestry can be identified for non-conventional energy generation.

Crops suitable for ravine plantation in Chambal:

The Chambal ravines are being flattened to add arable acreage, but cultivation this way seems to be a distant reality as of now keeping in view the resources and efforts being utilized. The ravines where erosion is less or started to increase steadily are suitable for growing horticultural crops whereas in extreme conditions adoption of Silvi-pastoral and Agroforestry systems may be taken up.

Fruit crops:

Fruit plants like bael, imli, karonda, ber, guava, aonla, custard apple, sweet orange, lime, pomegranate, phalsa, lasora, grow very well in this area and can be a good choice for the ravines. Likewise, fig (*Ficus carica*) has tremendous potential in the Chambal and Bundelkhand region. However, care should be taken that selected fruit species are capable of withstanding moisture stress.

Vegetables, spices, medicinal and aromatic and flower plants and Fodder crops:

Among vegetables and spices sweet potato, tomato, cabbage, cauliflower, drumstick, chillies, garlic, coriander, aniseed and cumin may be grown in the soils which are somewhat arable. Among medicinal & aromatic plants, guggal and adusa grow naturally and can be taken up in such degraded soils. Flower crops *viz.*, marigold, gaillardia and desi rose can be taken up in the undulating land but good soil. Fodder crops like berseem & chari can be promoted for production in ravines. Among grasses, *Dicanthium annulatum*, *Cenchrus ciliaris*, *Cenchrus setigerus, Panicum antidotale, Panicum maximum, Pannisetum purpureum,* and *Bracharia mutica* are some of the important species suitable for improving the fodder availability in ravine regions.

Agroforestry:

The trees should be suitable to grow in the degraded soil and undulating land conditions and provide a fast cover for protection against soil erosion. Species like *Acacia catechu* and *Dalbergia sissoo* with a dormant period during the summers may be grown in gully slopes and humps to overcome moisture deficiency in the soil. In the ravine beds where moisture availability is better than ravine top or side slopes, trees *viz.*, *Dalbergia sissoo*, *Tectona grandis*, *Eucalyptus* and *Dendrocalamus strictus* may be planted. In soil which are saline and alkali, trees *viz.*, *Acacia nilotica*, *Azadirchta indica, Albizia lebbeck* and *Prosopis juliflora* can be grown. Other trees of economic value like *Acacia spp., Leucaena leucocephala*, and *Prosopis juliflora* can be planted on ravine top and bottom.

However, emphasis should be given in selection and planting of appropriate trees/shrubs/herbs which are indigenous (Table 1 to 5) and well adapted to such climatic and soil conditions and need to be promoted as traditional land-use adaptation may also support livelihood through production of fruit, vegetables, fodder etc. as well as mitigation of the impact of soil degradation.

Policy issues:

In all 19 projects were undertaken in Chambal ravines area over 25 years, but only about 2,000 hectares of land could be reclaimed. There is a need to work in a holistic approach to address the ravine issues. However, it cannot be possible without proper policy issues with an integrated approach for the Ravines reclamation in the Chambal region. Recently, levelling of ravines for cultivation is thought of, but levelling for agriculture should not be attempted in those areas where slopes are steep or else it would disturb the ecological balance of the place and lead to more soil erosion. Afforestation should be the option for undulating and rocky waste/degraded lands. Also agro-forestry can be made an integral part of farming to meet needs of local people as also to enhance carbon sequestration. Policy measures for increased use of micro irrigation systems for enhanced water use efficiency and discourage use of tube-well water for summer rice cultivation. Overdevelopment (withdrawal > recharge) of ground water must be curtailed, even by regulating the use of electricity for it, and backstopped by recharge through effective rain water conservation. Also, strengthening of need based research on evaluating periodic and long term effects of agricultural and related activities on degradation of natural resources needs to be done for feasible and viable outcomes.

Table 1. Indigenous trees in Chambal ravines

S.No.	Botanical Name	Local Name
1.	**Fruit trees**	
i.	*Cordia dicotoma*	Lasoda
ii.	*Ficus palmate*	Karkara
iii.	*Moringa oleifera*	Sehjana
iv.	*Ziziphus mauritiana*	Ber
2.	**Trees for timber purpose**	
i.	*Acacia catechu*	Khair
ii.	*Acacia nilotica*	Babool
iii.	*Dalbergia sisoo*	Sisam
iv.	*Miliusa tomentosa*	Kari
v.	*Tectona grandis*	Sagon
3.	**Trees for fuel purpose**	
i.	*Acacia leucophloea*	Reuja
ii.	*Prosopis juliflora*	Vilayti babool
4.	**Trees for medicinal purpose**	
i.	*Azadirachta indica*	Neem
ii.	*Balanites aegyptica*	Hingot
iii.	*Bombax ceiba*	Semra
iv.	*Holoptelea integrifolia*	Papdi
5.	**Trees of religious importance**	
i.	*Ficus racemosa*	Gular
ii.	*Ficus religiosa*	Peepal
iii.	*Prosopis cineraria*	Chenkur
6.	**Trees of ornamental importance**	
i.	*Albizia lebbek*	Siris
ii.	*Delonix regia*	Gulmohor
iii.	*Butea monosperma*	Palash

Table 2. Common shrubs available in Chambal ravines

S.No.	Botanical Name	Local Name
1.	**Shrubs of medicinal importance**	
i.	*Adhatoda zeylanica*	Bamsori
ii.	*Calotropis gigantean*	Madar
iii.	*Calotropis procera*	Akauwa
iv.	*Commiphora wightii*	Guggul
v.	*Ricinus comunis*	Andora, Andi
vi.	*Salvadora oleoides*	Pilua
vii.	*Securinega leucopyrus*	Hartho

viii.	*Salvadora oleoides*	Pilu
ix.	*Ipomoea carnea*	Beshrum
2.	**Fruit yielding shrubs**	
i.	*Capparis decidua*	Kareel
ii.	*Ziziphus oenoplea*	Zariya
iii.	*Ziziphus nummularia*	Jher beri
3.	**Shrubs of ornamental value**	
i.	*Lantana camara*	Baramasi
ii.	*Agave Mexicana*	Hathichinghad
iii.	*Opuntia vulgaris*	Nagphani
iv.	*Grewia flavescens*	Jher kher
4.	**Shrubs for fuel**	
i.	*Dichrostachys cinerea*	Bilatri
ii.	*Mimosa himalayana*	Arali

Table 3. Commonly adapted Herbs of Chambal ravines majorly for medicinal use

S.No.	Botanical Name	Local Name
i.	*Achyranthes aspera*	Chir chita
ii.	*Adhatoda zeylanica*	Arusa
iii.	*Alhagi maurorum*	Javaso
iv.	*Ammannia baccifera*	Dadmari
v.	*Argemone mexicana*	Pili kateri
vi.	*Asphodelus tenuifolius*	Piazi, Pimalak
vii.	*Bacopa monnier*	Brahmi
viii.	*Boerhaavia diffusa*	Punarnava
ix.	*Buddleja asiatica*	Neemda
x.	*Cassia tora*	Puar
xi.	*Convolvulus prastratus*	Shankhbooti
xii.	*Echinops echinatus*	Untkatera
xiii.	*Euphorbia hirta*	Dudhi
xiv.	*Indigofera linnaei*	Bhuinguli, Atahai
xv.	*Lepidagathis cristata*	Chekna
xvi.	*Occimum gratissimum*	Nagad basuri
xvii.	*Ocimum tenuiflorum*	Tulsi
xviii.	*Solanum virginianum*	Bhatkataiya
xix.	*Tephrosia tinctoria*	Dhamasa
xx.	*Tribulus terrestris*	Gokhru
xxi.	*Xanthium indicum*	Bada gokharu

Table 4. Common Climbers of Chambal ravines majorly used for medicinal purpose

S.No.	Botanical Name	Local Name
i.	*Asparagus racemosus*	Shatawar
ii.	*Cascuta reflexa*	Amarbel
iii.	*Cayratia trifolia*	Tipani
iv.	*Clitorea ternatea*	Aparjit, Kajroti
v.	*Cocculus hirsutus*	Chirenta
vi.	*Cryptolepis buchanani*	Nagbel
vii.	*Gloriosa superba*	Kalihari
viii.	*Hemidesmus indicus*	Belas
ix.	*Ipomoea pestigridis*	Panch-patri
x.	*Mucuna pruriens*	Dondiya
xi.	*Pergularia daemia*	Sadowani
xii.	*Tinospora cordifolia*	Giloy

Table 5. Common grasses available in Chambal ravines

S.No.	Botanical Name	Local Name
1.	**Grasses for fodder use**	
i.	*Apluda mutica*	Dinanath
ii.	*Aristida funiculate*	Lappa
iii.	*Bulbostylis barbata*	Masa
iv.	*Dactylictenium aegyptium*	Makra
v.	*Chloris barbata*	Jarghas
vi.	*Heteropogon contortus*	Kusal, Lampa
2.	**Grasses of medicinal importance**	
i.	*Cynodon dactylon*	Doob
ii.	*Cyperus rotundus*	Nagarmotha
3.	**Grass for fibre**	
i.	*Saccharum spontaneum*	Kans

(Tables adapted from Jain, 2005)

Technological interventions in dryland horticulture enriching fruit growers

A.K. Singh, Sanjay Singh, D.S. Mishra and P.L. Saroj

The drylands are characterized by poor soil and water resource availability and shelter a majority of the rural population in India. Enhancing the productivity of drylands is essential in order to achieve sustainable and more widely spread growth in India, unlike with irrigated horticulture, achieving dramatic yield gain is difficult in dryland horticulture . Therefore, it is required to plan for gradual increase in crop yield by making more efficient use of available resources in semi arid regions. Efforts can be made to create awareness among farmers, fruit and vegetable growers regarding innovative technologies such as use of high yielding and suitable cultivars for dryland areas and their multiplication, water harvesting practices, integrated nutrient management, mulching, organic farming, technologies to increase shelf life of fruits along with value addition of the products and marketing. Which in turn will help to increase economic level and livelihood security of the horticultural farmers of semi arid regions.

The nature-dependent lands are rich in horticultural diversity, resistance against biotic and abiotic stresses, and have the potential for quality production of fruits, vegetables, flowers, and spices. Indian dryland is characterized by high temperature, erratic rainfall, poor soil, and water quality, limiting productivity. However, these conditions can favorably enhance productivity through advanced horticultural technological interventions resulting in better income by utilizing solar and wind energy, human workforce, and developing infrastructure, greatly favoring the farming community's income.It is now realized that there is plenty of scope for a quantum jump in fruit and vegetable production in dryland areas. Several fruit crops such as ber, aonla, bael, pomegranate, tamarind, jamun, chironji, custard apple, wood apple, karonda, lasoda, fig, and in vegetables such as cucurbits, legumes, and solanaceous vegetable crops, spices, flower crops, medicinal and aromatic plants can be grown in semi-arid dryland areas for higher economic return. The existing low productivity could be doubled by following improved new sustainable technologies and inputs without irrigation. The amelioration of the extreme conditions is also considered vital for life support to this area's inhabitants. The recent awareness regarding the potential of these ecologically fragile lands for the production of quality products has opened up avenues for providing sustainability in livelihood and nutritional security for this region's people and bringing in new are as to increase horticultural production. The area expansion and yield potential of arid horticultural crops have increased many folds because of the development of new varieties and advancement in agro-techniquesand processing techniques to develop value-added products rich in health-promoting compounds.

View of soil profile in semi-arid region

Rainfed semi-arid horticulture supports the dwellers' livelihood and plays a significant role in nutritional and income security and environmental security. The implication of untapped potential of natural resources and application of new production

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technologies suits to dry climate can double the farm income of arid tracts of the country. Production of seeds and quality planting material of dryland horticultural crops on a large scale, the horticultural basket can provide food, nutrition, and livelihood security to the farmers of semi-arid regions with doubling farm income.

Constraints of dryland areas

Indian semi-arid zone occupies nearly 37 percent of the total geographical area (131m ha) of the total 329 m ha of the country's geographical location and spread over in Maharashtra (19%), Karnataka (15%), Andhra Pradesh (15%), Rajasthan (13%), Gujarat (9.5%), Tamil Nadu (10%), Uttar Pradesh (7%) and Madhya Pradesh (6%) over 38.7 million ha (cold and hot zone) in various states of the country. The semi-arid region is characterized by moisture stress and poor soil and water quality. The annual average rainfall in the semi-arid areas ranges between 200-500 mm, which is 2 to3 times less than the potential evapotranspiration. Therefore, the crop selected for the region must be abiotic stress-tolerant and should have the reproduction phase synchronized to the maximum moisture availability period. The prevailing stress conditions necessitate special technologies relating to the use of suitable cultivars, propagation technologies and cultural practices, plant-protection measures, and utilization methods to realize maximum value. In the semi-arid region, the large number of farming community have small land holdings and poor resources, and cannot afford the burden of credit with available resources, but they can generate income by using scientific dryland horticultural technologies.

Economically potential horticultural crops

Fruit crops

The region has strength to produce high quality ber (*Ziziphus mauritiana*), aonla (*Emblica officinalis*), bael (*Aegle marmelos*), pomegranate (*Punica granatum*), lasoda (*Cordia dichotoma*), khirni (*Monilkara hexendra*), karonda (*Carissa congesta*), jamun (*Syzygium cuminii*), chironji (*Buchanania lanzan*) tamarind (*Tamarindus indica*), wood apple (*Feronia limonia*), custard apple (*Annona squamosa*), fig (*Ficus carica*), phalsa (*Grewia subinaequalis*), mulberry (*Morus nigra*), acidlime (*Citrus aurantifolia*), manila tamarind (*Pithecellobium dulce*), timru (*Diospyrus melenoxylon*) and mahua (*Madhuca indica*) and Palmyra palm (*Borassus flabellifer*) in fruit crops.

Vegetable crops

Vegetable crops such as guar or cluster bean (*Cyamopsis tetragonoloba*), cowpea (*Vigna unguiculata*), dolichos bean (*Dolichos purpureus*), moth bean (*Vigna aconitifolia*), Cucurbits *viz.*, cucumber (*Cucumis sativus*), pumpkin (*Cucurbita moschata),* Bottle gourd (*Lagenaria siceraria*), bitter gourd (*Momordica charantia*), sponge gourd (*Luffa cylindrica*), ridge gourd (*Luffa acutangula*), ash gourd (*Benincasa hispida*); ivy gourd (*Coccinia indica*), spine gourd (*Momordica dioica*), pointed gourd (*Trichosanthus dioica*) etc., solanaceous vegetable crops *viz.*, brinjal, tomato, chili, capsicum, etc., drumstick, bhindi, garlic, and onion are vegetable crops rainfed semi-arid areas that can be extensively utilized with improved technological intervention to enhance the income of farmers.

Spices

During the winter season, wherever irrigation facilities are available, farmers can grow cumin, fennel, fenugreek dill, coriander, ajwain, nigella, etc. These spices are considered as 'cash crops' because even under limited irrigation or without irrigation with proper planning can earn a substantial amount of income. These spices can be intercropped with fruit crops for enhanced farm income through export earnings.

Medicinal and aromatic plants

Medicinal plants like isabgol (*Plantago ovata* Forsk.), aloe (*Aloe vera*), senna *(Cassia angustifolia),* Egyptian Henbane (*Hyoscyamus muticus*) and aromatic plants *viz.,* palmarosa (*Cymbopogon martini*), lemongrass *(C. flexuosus)*, and Vetiver *(Vetiveria zizanioides)* can be cultivated as an intercrop under dryland conditions to enhance the current farm income.

Plant genetic resources and suitable cultivars for dryland areas

Among the ber genotypes, the ber varieties Gola, Seb, Umran, Kaithali, and Banarasi Kadaka perform well under rainfed semi-arid climatic conditions. Among the pomegranate genotypes, Bhagawa, Ganesh, G-137, Mridula, and Phule Arakta are the better genotypes for fruit yield and quality. The varietal evaluation of aonla revealed that the NA-7 followed by Goma Aishwarya and NA-6 are prolific bearers under dryland conditions. Goma Yashi bael variety developed by CHES (CIAH), Godhra is becoming popular among farmers of dry tracts of the country due to high yield potential and better fruit qualityand its suitability to high density (5mx5m) under semi-arid conditions. Full-grown trees can yield 200-300q/ha and can double the income over the traditional system of cultivation. Thar Divya variety of bael ripens early (February) and not suffered by any disorders can be potentially exploited by the processing industry. Among bael varieties, CISHB-1, NB-5, and NB-9 are performed better under rainfed semi-arid conditions of Godhra Gujarat. These varieties can give yield 60-100kg during the 9^{th} year of orchard life. Similarly, jamun variety Goma Priyanka and Drumstick variety Thar Harsha can provide higher yield and fetch more revenue under dryland conditions. Looking into the importance of under exploited and less known fruit and vegetable crops having commercial potentials in semi-arid regions, intensive crop-specific surveys of diversity rich areas and explorations has been undertaken in the semi-arid areas. Many landraces, semi-cultivated, and popular types of various horticultural crops have been collected over the years for systematic evaluation, characterization, and indigenous germplasm conservation. The station has developed several varieties of semi-arid fruit and vegetables like ber (Goma Kirti), bael (Goma Yashi, Thar Divya, and Thar Neelkanth), aonla (Goma Aishwarya), jamun (Goma Priyanka and Thar Karanti), khirni (Thar Rituraj), chironji (Thar Priya), karonda (Thar Kamal), mahua (Thar Madhu), phalsa (Thar Pragati), pomegranate (Goma Khatta), drumstick (Thar Harsha), pumpkin (Thar kavi) and cluster bean (Goma Manjari).

Khirni variety: Thar Rituraj

Mahua variety: Thar Madhu

Criteria for selection of fruit crops and varieties for a rainfed semi-arid region

The agro-climatic conditions of the semi-arid region are not ideal for the sustainability of most of the horticultural crops hence; selection of a plant species for such region is an important factor for growth and sustainable production. While selecting the crops for dryland horticulture, one of the basic requirements is that those crops that complete their vegetative growth and reproductive phase during maximum moisture availability should have opted. The fruits such as ber, guava, pomegranate, custard apple, aonla, and sour lime conform to these prerequisites. The crops must have characters such as deep root system (e.g. aonla, ber), summer dormancy (e.g. ber, custard apple), high 'bound water' in the tissues (e.g. cactus pear, fig), reduced leaf area (e.g. Indian gooseberry, tamarind), leaf surface having sunken stomata, thick cuticle, wax coating and pubescence (fig, ber, phalsa, tamarind), and ability to adapt to poor soil, rocky, gravelly, and undulating wastelands (pomegranate, khirni, chironji, aonla, mahua, bael, and acid lime) whereas for the selection of varieties, drought endurance, high yielding with minimum moisture availability in soil and atmosphere should be given priority. Varietal variation in endurance to drought has also been observed in horticultural crops. Early ripening cultivars seem to escape stress conditions caused by the receding soil moisture stored in the soil profile during the monsoon. Ber cultivars Gola, Seb, and Mundia for extremely dry areas, Banarasi Kadaka, Kaithli, Umran and Maharwali for dry regions have been recommended. Similarly, kaith, chironji, khirni, bael strains evaluated showed drought hardiness.

The varietal wealth of horticultural crops

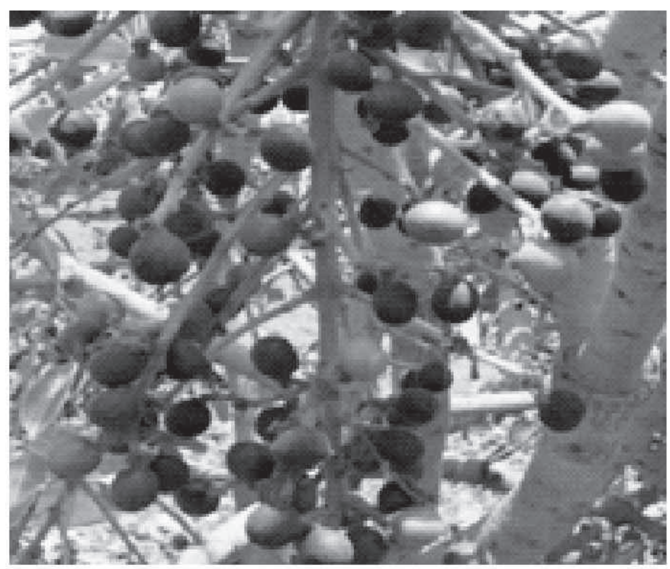
Fruit crops

In fruit crops, the varieties of ber (Gola, Goma Kirti, Umran and Seb), bael (Goma Yashi, Thar Divya, Thar Neelkanth, Thar Srishti, NB-9, NB-5, CISHB-1 and Pant Aparna), aonla (NA-7, NA-6, Goma Aishwarya, Chakaiya and Anand-2), custard apple (Balanagar and Mammoth), guava (Lalit and Allahabad Safeda and L-49), tamarind (Goma Prateek and Pratishthan), jamun (Goma Priyanka), fig (Poona fig, Dianna and Excel), karonda (Thar Kamal), chironji (Thar Priya), phlasa (Thar Pragati), khirni (Thar Rituraj), mango (Dashehari, Kesar and Mallika) and mahua (Thar Madhu) have the potential to increase the yield with proper orchard management practices.

Fruiting behavior in bael variety Goma Yashi

Vegetable crops

In vegetable crops, the varieties of drumstick (Thar Harsha), pumpkin (Thar Kavi, Arka Chandan, Gujarat pumpkin-1, CO-2), bottle gourd (Pride of Gujarat, Pusa Naveen and Arka Harit), cowpea (Pusa Barsati, Pusa Naubahar, Pusa Komal, Anand Cowpea-1),tomato (Gujarat tomato-1 and Gujarat Tomato-2), chili (Pusa Jwala, Mathania, Pant C-1, GVC-111, GCV-121, GCV-131, Bharat), cluster bean (Goma Manjari, Pusa Mausami, Pusa Navbahar, Durga Bahar, AHG-13), okra (Punjab No. 13, Punjab Padmini, P-7,GO-2, GO-5, Parbhani Kranti), Muskmelon (Pusa Sharbati, Pusa Madhuras, Hara Madhu, Punjab Sunehri, Durgapura Madhu), watermelon (Sugar Baby, Durgapura Meetha, Kesar, bitter gourd (Pusa Do Mausmi, Arka Harit, Pride of Gujarat), Amaranth (Co-1), brinjal (Doli-5 and Gujarat brinjal hybrid-1),coccinea and pointed gourd (Padra local) are ideally suitable to cultivate commercially under dryland conditions.



Fruiting behavior in chironji variety Thar Priya

Medicinal and aromatic plants

Medicinal plants like isabgol (Gujarat Isabgol-1 and Gujarat Isabgol-2), Aloe (*Aloe vera*), Senna *(Anand Late selection), Egyptian Henbane* (HMI-80-1) are the varieties of medicinal plants, and Palmarosa (Rosa Gross-49a), Lemongrass (NLG-84) and Vetiver

(Hyb-8), the varieties of aromatic plants that can be cultivated commercially under dryland conditions to generate additional income through crop diversification.

Spices

Spices varieties of cumin (GC-4), fennel, fenugreek (Ajmer fenugreek-4, high yielding), till, coriander, ajwain (Ajmer ajwain-93, early maturing), nigella (Ajmer nigella-20, high yielding)are suitable cultivars and can be utilized for income generation through crop diversification or multi-story cropping system. These spices can be cultivated with fruit crops for enhanced farm income through export to earn foreign exchange.

Technological intervention for enhanced productivity and income generation

Development of water harvesting module

Investments are needed in institutional and human capacities to plan and manage water for rainfed horticulture at the catchment scale. Local runoff water resources can be diverted, stored, and managed. Under dryland conditions, tapping the potential lies in the availability of an adequate but erratic water resource provided by the rain. The major water-related challenges for rainfed horticulture in semi-arid regions are the extreme variability in rainfall, characterized by few rainfall events, high-intensity storms, and high frequency of dry spells and droughts. It is therefore critical to understand how hydroclimatic conditions and water management affecting yields in rainfed horticulture. However, construction of earthen and concrete check dam according to the catchment area, development of micro catchment module, full moon, half-moon terracing, and the help of Horti-Silvi-pastoral system, water loss could be minimized under dryland conditions.

Orchard floor management

Under dryland condition, inter cropping during initial years of orchard of bael, aonla and jamun had no adverse effects on plant growth for up to 7 years. However, intercropping in the orchard spaced at 10mx10m can be done for up to 10 years. Intercropping of guar, cucurbits, okra, and leguminous vegetable crops increased the income 2-3 times. Cultivation of guar in orchards gave the additional advantage of 800 kg seed yield than cowpea. Cover cropping with lobia, moth bean was found to increase the water-holding capacity of light soils due to increased organic carbon content in these regions. Among the different cucurbits tried as intercrops, aonla + bottle gourd fetches more net economic return (Rs. 147312.80/ha) with the B: C ratio of 4.44 under rainfed conditions of western India's semi-arid ecosystem. Intercropping is economically viable for increasing productivity per unit area and minimizes crop failure during drought years (Table-1).

Protected cultivation

High input costs and low-cost structures can be raised to grow crops during the offseason. Due to harsh environmental conditions, protected cultivation is useful to increase production and income by growing high-value crops in dryland conditions. Vegetables like cucumber, capsicum, tomato, and flowers like gerbera, orchids, etc., can be grown year-round and income can be enhanced manifold with proper management.

Fruit-based cropping models for crop diversification

Various fruit crop models can be adopted under dryland conditions to minimize risk and enhance productivity. Bael, aonla, and jamun based cropping models are beneficial in terms of improved yield and

Table 1. Cost-benefit ratio aonla based intercropping

Inter crops	Details of cost and benefits from intercrops					Details of cost benefits from sole crop aonla					B:C ratio		
	Produce of intercrop (q/ha)	Rate (Rs/kg)	Cost of cultivation /ha (Rs.)	Gross income (Rs.)	Net income (Rs.)	Produce of main crop (q/ha)	Rate (Rs/kg)	Cost of cultivation (Rs.)	Gross income (Rs.)	Net income (Rs.)	Input costs (Rs)	Total net Return (Rs)	B:C ratio
Bottle gourd	79.95	15.00	18142.20	119925.00	101782.80	60.53	10	15000	60530.00	45530.50	33142.20	147312.80	4.44
Pumpkin	74.40	10.00	17225.00	074400.00	057175.00	58.35	10	15000	58350.00	43350.00	32225.00	100525.00	3.11
Bitter gourd	49.14	15.00	18035.50	073521.00	055485.50	56.03	10	15000	56030.00	41030.40	33035.50	96515.00	2.92
Cucumber	68.61	10.00	16054.83	068610.00	052555.17	52.85	10	15000	52850.00	37850.00	31054.83	90405.17	2.91
Sponge gourd	43.73	10.00	15147.57	043730.00	028582.43	59.50	10	15000	59500.00	44500.07	30147.57	73082.43	2.42
Control	-------	------	---------	-----------	--------	64.65	10	15000	64650.00	49650.52	01500.00	49650.00	------

income. Bael + aonla + karonda + drumstick, bael + chironji + fig + custard apple, bael+khirni+phalsa +wood apple cropping models are useful to enhance the productivity of dryland tracts of the country. Layout and plantation of these crops should be done at closer spacing with proper canopy management to double productivity and income.

High-density planting and canopy management

India is the homeland of many semi-arid, drought-hardy fruit crops like bael, aonla, acid lime, charoli, mahua, etc. However, the productivity of all these fruits in India is very low (4-5 t/ha) compared with other major fruit crops grown in India. Many reasons may be attributed to low productivity. A need to develop high yielding varieties/hybrids resistant to biotic and abiotic stresses having dwarf stature and responding to the pruning to solve this problem. By adopting the scientific practices of canopy architecture management and high-density planting, yield can be doubled in lesser time and from the more secondary area. High-density orcharding results in early bearing, helping to minimize weed problems. High-density planting at a spacing of 5 m x5 m in bael, aonla, jamun, chironji, and mahua has been found to double the yield and reduce the traditional planting system's harvesting. However, crops like phalsa, pomegranate and karonda can be accommodated at lesser spacing with the help of proper training and pruning. By adopting a double hedgerow system of planting, the productivity and income per unit area can be enhanced to 2-2.5 times over the conventional square system of planting under the rainfed condition. Bael, ber, and aonla are recommended for planting at 5mx5m distance under semi-arid conditions. However, a high-density plantation study revealed that maximum plant height was noticed in 2.5 x 2.5m planting distance and tripled the yield over the traditional planting system(5mx5m). In contrast, plant height, stem girth, the average number of fruits, the average weight of fruit, and yield was obtained under 5mx5m distance in pomegranate under Godhra conditions. High-density planting is also beneficial in aonla fruit trees to achieve high yield under semi-arid conditions.

Integrated nutrient management

India's soils of semi-arid regions are poor in organic carbon, nutrients, and water holding capacity. Soil depths of the soil in these regions are less, and nutrient management becomes difficult due to the presence of calcium carbonate layer at a lower depth. Improved fertilizer management is required to grow crops successfully on such soils. To avoid ammonia volatilization, fertilizers containing ammonium-N or urea should be moved into the root zone with rainfall or irrigation or be incorporated into the ground. Band placement of P minimizes soil contact, thus reducing or delaying the formation of insoluble Ca and Mg phosphates. Crops planted on calcareous soils may require above-average levels of K and Mg fertilizer for satisfactory nutrition. Using tolerant rootstocks and varieties reduces the severity of nutrient-related disorders. The deficiency of micronutrients can be corrected through foliar application ofchelates. Adequate K supply and organic matter application in the form of cakes, FYM, and organic wastes can improve microelements' availability.

Mulching

Continuous use of organic mulches helps improve the soil physic-chemical properties, microbial flora, earthworm population, and soil aeration and moisture-holding capacity, which ultimately resulted in better growth and yield of the plant. Under semi-arid conditions, the application of organic mulch (paddy straw, grasses, maize straw, etc.) in three basins is beneficial for the successful cultivation of fruit crops like bael, jamun, aonla, custard apple. It reduces the moisture loss from the soil, enhances the rate of rain water absorption in the soil, and controls weed growth. Mulching can be done with any locally available organic material. Mulching with paddy straw, maize straw, grasses, and rice husk reduces the weed population and conserves the soil's moisture. Mulches should be applied in the tree basin (20 cm thick) after the rainy season, and non-decomposed organic mulches should be incorporated and mixed with the soil of the tree basin in the forthcoming monsoon. Organic mulches improve the soil properties and moisture-holding capacity, reduce soil temperature (2 to 8^{O}C) during summer, and increase the yield of 20-25 percent under dryland conditions.

Organic farming

Most of the minor horticultural crops of India's semi-arid regions are often available only in the local markets and are practically unknown in other parts of the world. Today, consumers are becoming increasingly conscious of the health and nutritional benefits of their food basket. The minor horticultural crops are rich in minerals, vitamins, therapeutic values, and they can serve this purpose as they are growing naturally; therefore, they are free from toxic chemicals. To achieve this, these fruits need to be popularized in national and international markets. Practically, it can be achieved by developing suitable processing and marketing strategies for minor horticultural crops. In this regard, attempts have been made as aonla, pomegranate, guava, karonda, and bael and aonla based organic products are becoming more popular in the domestic markets. The growing of crops through organics not only hikes the price of products but also improves soil health.At CHES, Godhra, among the different combinations of an organic source of nutrients; the treatment combination FYM + *neem* cake +CPP and FYM + *Azotobactor* + VAM recorded 63.45kg and 67.12kg/tree in NA-7aonla during 8th year with improved TSS, total sugar, vitamin C and total phenols.

Value addition

Malnutrition in resource-poor areas of semi-arid tropics is a significant problem, particularly in pregnant women and children. Fruits like aonla, custard apple, bael, khirni, karonda, pomegranate, and ber are a rich source of vitamins, minerals, and dietary fibers. Ber fruits contain higher protein than even apples. Fruits like wood apple and custard apple are rich in carbohydrates and minerals, vital for maintaining the body. These fruits are highly perishable, the marketing of which is a significant problem, e.g.,custard apple get spoiled within 2–3 days of harvesting, if not consumed. Also, with the glut in the market, these fruits' prices drop down drastically, making it uneconomical for the farmers to sustain production; the result is that the farmers uproot the trees. To avoid the situation, there is a need to extend these fruits' shelf life and develop post-harvest value addition technologies that are simple and adaptable at the farm level. This will result in developing small-scale industries and employ the rural masses throughout the year, resulting in an increased income of both farmers and workers. Efforts made at the station were successful and many products, *viz.*, dried and dehydrated fruits, RTS, squash, fruit bars, candies, fruit concentrates, powders, wines, and condensed fruit juices through solar drying, were prepared. Pomegranate varieties with dark red arils are preferred in making fruit juice and carbonated drinks. The tamarind pulp is pressed and preserved in large masses, and in dry conditions, the pulp remains good for about 1 year. There is tremendous scope for preparing beverages from the ripened fruit of chironji. Kernels are being used for the preparation of different kinds of sweets. The products like squash, RTS, and nectar may be prepared from the pulp of the fruit.

Keeping in view the agro-climatic conditions of the semi-arid region, it is need of the hour to create awareness among the farmer regarding the various technologies like high yielding varieties, water harvesting practices, use of organics, IPM, IDM, bio-pesticides,bio-fertilizers, preparation of value-added products and their marketing can double the productivity and income in the dryland semi-arid conditions. Unproductive land can be made productive by selecting the crops with the ability to grow under aberrant agro-climatic conditions by adequately planning and amalgamating dryland technologies holistically. As most of the semi-arid dryland fruits cannot be directly used for the table purpose, thus fetching low prices in the market. Therefore, through processing and value addition and their efficient marketing, farmers' economic status of the country's dry tract can be effectively improved.

Production technology of leaf vegetable amaranth under rain-fed condition

Harpal Singh[1] and Amit Tomar[2*]

Amaranthus is the name given to a group of approximately 70 species of annual or short-lived perennial plants in the genus Amaranthus including edible weeds native to the US, such as *Amaranthus retroflexus* (redroot pigweed). Amaranths are branching broad-leaved plants with egg-shaped or thombic-leaved, which may be smooth or covered in tiny hairs. The leaves have prominent veins, can be green or red in color, and have long petioles. The plants produce single flowers on terminal spikes, which are typically red to purpose in color. Amaranthus can reach up to 2.5 m (6.6 ft) in height and are usually grown as annuals, harvested after one growing season.

Amaranth is the most common leaf vegetable grown in Kerala and Tamil Nadu. Leaves and succulent stem are good sources of iron (38.5 mg/100g), calcium (350-400 mg/100g), vitamin A and vitamin C. Absorption of calcium from amaranth are, however, poor. The iron availability is only about 15.2-53.6% of total iron. High oxalate content (1-2%) and nitrate (1.8-8.8 g/ kg dry matter) levels are reported from various species' leaves. Short duration, quick response to manures and fertilizers, high yield, easiness in cultivation, and availability of diverse types suited to specific agro-climatic situations make it a favorite crop of farmers to fit in any cropping systems. Both leaf and grain types play a vital role in combatting malnutrition of poor people.

Origin and distribution: Centres of diversity for amaranth are Central and South America, India, South East Asia, with secondary centers of diversity in West and East Africa. Leaf amaranth is a native of India. Taxonomists recognize two sections in *Amaranthus, viz., Amaranthus and Blitopsis,* Section A*maranthus,* includes important grain types where the inflorescence is terminal. Section *Blitopsis* includes leaf types, and flowers are borne in clusters in leaf axils. The majority of leaf cultivars grown in India belong to *Amaranthus tricolor.* Major species found in India are:

A. tricolor (Syn) A. *gangeticus,*	
A. mangostanus,	cultivated - leaf type
A. polygonoides	
A. dubius	cultivated -leaf type
A. blitum (Syn: *A. lividus*)	cultivated - leaf type
A. tristis	wild- leaf type
A. viridis	wild- leaf type
A. spinosus	cultivated - grain type
A. cruentus	cultivated - grain type
A. caudatus	cultivated - grain type

Varieties: Cultivated leaf amaranth varieties and cultivars differ in size, shape, and colour of leaves and stem, the position of inflorescence, etc., and belong to different species. A brief description of improved varieties developed by different Research Institutes is given below:

Sirukeerai (*A. polygonoides*) is a traditional cultivar in Tamil Nadu, suited for uprooting at 25 days after sowing; leaves are small, ovate with blunt bifurcated tip, and have long petiole; collar region is dark pink, and at leaf axil a miniature branch initiates.

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A. tricolor

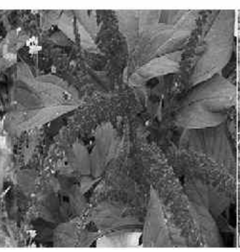
A. viridis

A. tristis

A. blitum

A. dubius

A. spinosus



A. cruentus

A. caudatus

Indian Agricultural Research Institute (IARI), New Delhi:

Pusa Chotti Chaulai (*A. blitum*): Plants dwarf with succulent, small, and green leaves; responds well to cutting.

Pusa Badi Chaulai (*A. tricolor*): Plants tall and stem thick with large green leaves; response to cutting.

Pusa Kirti (*A. blitum*): Green leaved variety with the green and thick stem; leaf lamina broad ovate; ready for harvest in 30-35 days and extends up to 70-85 days; yield 55 t/ha; specifically suited for summer.

Pusa Kiran (*A. tricolor*): This is developed by natural crossing between *A. tricolor* and *A. tristis* and has more characteristics of *A. tricolor*. Leaves are glossy green with broad ovate lamina; leaf-stem ratio is 1.0:4.6; yield 35 t/ha in 70-75 days; suited for the *kharif* season.

Pusa Lal Chaulai (*A. tricolor*): Upper surface of leaves are deep red and lower surface purplish red; yield 45-49 t/ha in 4 harvests.

Tamil Nadu Agricultural University, Coimbatore:

CO.1 (*A. dubius*)	This tetraploid variety was developed by selection from ("local germplasm. Stem and leaves are dark green; leaf- stem ratio is 2.0; inflorescence terminal and axillary; lacks initial vigour but makes rapid growth after 30 days; suitable for late harvest; resistant to Rhizoctonia leaf blight; green yield 8.0 t/ha; seed yield 1.5 t/ha.
CO.2 (*A. tricolor*)	Stem and leaves green, leaves lanceolate and slightly elongate, leaf-stem ratio 1.8; suited for early harvest; yield 10.78 t/ha.
CO.3 (*A. tristis*)	This is specifically suited for clipping of tender greens and is locally known as 'Araikeera' in Tamil. Leaves are small and green; the stem is slender and tender. The first clipping is possible in 20 days after sowing. Nearly 10 clippings can be taken over 90 days. Due to the very high leaf- stem ratio, cooking quality and the taste are excellent. Special care is required in land preparation for the variety.
CO.4 (*A. hypochondriacus*)	This grain type makes rapid vegetative growth within a period of 20-25 days. Plants are dwarf; grain yields 2.0-2.5 t/ha in 80-90 days.
CO.5 (A. tricolor)	It leaves double colored with Green and pink and is free from the fiber. It gives a rosette growth in the early stages, and the first harvest is possible in 25 days; yield 40 t/ha in 55 days.

Indian Institute of Horticultural Research (IIHR), Bangalore:

Arka Suguana (*A. tricolor*): A multicut variety with broad green leaves. First picking starts in 24 days after sowing and continues up to 90 days. Moderately resistant to white rust. Yield 17- 18 t/ha.

Ark Arunima (*A. tricolor*): A multicult variety with broad dark purple leaves. First picking starts in 30 days after sowing and two subsequent cuttings at 10-12 days intervals. Yield 27 t/ha.

Climate and soil: Amaranthus is widely distributed in both tropical and sub-tropical regions. Leaf amaranth is a warm-season crop adapted to hot, humid climatic conditions. It is grown throughout the year in the tropics and autumn, spring, and summer seasons in temperate regions. Most leaf types are day-neutral inhabit but differ in their day length requirements and respond differently to changes in photo and thermoperiodism. Grain types, *A. caudatus, A. cruentus* and *A. edulis* are short-day species, while *A. hypochondriacus* is day-neutral. Amaranth comes up well in well-drained loamy soil rich in organic matter. The ideal pH is 5.5-7.5, but some types can come up in soils with high pH. Red amaranth requires bright sunlight for color development.

Land preparation and sowing: Cultivation practices differ according to the method of harvest, duration, growth pattern of variety, etc. The land is prepared to a fine tilth by thorough plowing and harrowing. Well decomposed and powdered organic matter @ 20-25 t/ha is incorporated with the soil at the final plowing time.

Direct sowing: For direct sowing, the field is divided into small plots of about 3.0-3.6 m long and 1.5-1.8 m width, with irrigation channels running between every two plots. In case of irrigation by pot watering, reduce the width of plots to 90-100 cm. Amaranth seeds, being small in size, are mixed with fine sand and sown uniformly by broadcasting. The seeds are covered either by raking up soil and covering it with a thin layer of sand or soil. This is followed by light irrigation. Soil is kept moist by frequent irrigation. Grown-up seedlings are selectively pulled out at 30 days after sowing and marketed in small bundles along with roots. The seed rate for direct sowing is 2.0-2.5 kg/ha. After first pulling, urea is broadcasted in beds and irrigated for quick growth of remaining seedlings so that second pulling out is possible 10-15 days after first pulling. This is repeated, so that final pulling is over by 55-60 days after sowing.

Transplanted method: This is mainly practiced for multi-cut varieties. After thorough ploughing and leveling, the land is made into shallow trenches / basins of 50-60 cm width and convenient length. Well decomposed farmyard manure is applied in trenches and thoroughly incorporated into the soil by digging. 20-25 days old seedlings, already raised in a nursery, are transplanted in trenches at 20- 25 x 10-15 cm spacing. The seed requirement for the transplanted crop is only 500 g/ha.

Manures and fertilizers: Amaranth is a heavy feeder and high yielding crop. 20-25 tonnes of FYM and 50:25:20 kg NPK / ha are recommended as a basal dose. Under the pulling out method, 20 kg N should be top-dressed twice during subsequent pulling out of seedlings. For clipping varieties, a still higher dose of 75:25:25 is advisable. Apply N after every clipping or cutting. Foliar spray of 1% urea or diluted cow urine at every harvest is good for promoting further growth and high yield.

Irrigation: Grain amaranth is a drought-tolerant crop, but leaf amaranth requires frequent irrigation to keep the soil moist. The frequency of irrigation depends on soil.

Interculture: Amaranth is a short duration and shallow-rooted crop. Provide light hoeing to prevent soil crust formation after irrigation and to keep the soil loose. The field also should be kept weed-free, especially during the initial stages.

Harvesting: Amaranth is harvested early in the morning by pulling out or by clipping. In the first method, grown-up plants are pulled out at 30, 45, and 55 days after sowing, along with roots, washed and sent to market in small bundles. In the multi-cut method, first clipping or cutting is done 25-35 days after sowing. Subsequent cuttings are made at weekly intervals in Chhotti Chaulai and 10 days intervals in Badi Chaulai.

Bolting: Premature flowering or bolting is a serious problem in the cultivation of amaranth. Quality and yield deteriorate after flowering. Bolting is usually associated with the planting of short-day varieties during November-December, deficiency of nitrogen, extremely high temperature, and poor soil aeration.

Practices like raising of the crop at an ideal time depending on locality, frequent application of nitrogen fertilizers and manures, and keeping the soil loose by light hoeing prolong flowering.

Seed production: Provide an isolation distance of 400 m for foundation and 200 m for certified seed production in amaranth. For seed production, seedlings are transplanted at a wider spacing of 30-45 x 30 cm. Crop may be left for seed production after making one or two cuttings for vegetable harvests. The inflorescence is harvested when glumes turn brown in colour and seeds turn black. Spikes are initially dried in the sun to 15% moisture. After drying, the inflorescence is threshed with pliable bamboo sticks for the separation of seeds. Seeds are then winnowed and sieved through a 2 mm sieve. Seeds are finally dried to 7% moisture and stored. Seed rate varies from 450 kg to 500 kg/ha.

Major diseases: Major disease problems in amaranth cultivation are as follow :

Leaf blight (*Rhizoctonia spp*): Leaf blight disease is the most severe during the rainy season under warm and humid conditions. Symptoms include the appearance of white and irregular spots on the leaf lamina, making the produce unmarketable. The package suggested for control of leaf blight is given below:

- Sow resistant green amaranth variety, CO-1 during the rainy season
- Avoid splash irrigation
- Spray Mancozeb @ 4g/1 of cow dung supernatant as fine droplets. Cover plants thoroughly, so that spray solution reaches under surfaces of leaves also.

Anthracnose (*Colletotrichum gloeosporiodes)* :

Symptoms: Necrotic lesions on leavesdieback of leaves and branches.

Management: Avoid damaging plants and creating wounds for a pathogen to enter plant resistant varieties.

Damping –off (*Rhizoctonia* spp.):

Symptoms : Poor germination seedling collapse brown-black lesions girdling stem close to soil lime seedling fail to emerge from the soil, diseases emergence favors wet soils.

Management: Avoid planting seeds too deeply. Do not plant seeds too thickly to promote air circulation around seedlings. Do not over-water plants.

Wet-rot (*Choamephora cucurbitarum)* :

Symptoms : Water-soaked lesions on stems have hairy appearance due to the presence of fungal spores, may cause loss of leaves. Fungus mainly attacks plants that have been damaged by insects or by mechanical means spread by air currents and via infected seed. Disease emergence favors warm, moist conditions.

Management: Use certified seed of resistant varieties to disease. Do not plant crop densely. Treat affected crop with copper fungicides. Plant varieties resistant to disease only use certified seed do not plant crop densely treat disease with copper fungicides if it emerges.

Major pests:

Amaranth stem weevils: *Hypolixus truncatulus, H. nubilosus*

Damage Symptoms:

- Adults cause damage by feeding on the leaves, making irregular scratches on the tender stem, and sometimes eating up all the stem's inner contents leaving behind only the epidermis and hypodermal tissues.
- Larvae cause damage through tunneling within the stems in a zig-zag way, which reduces the vitality and vigor of the plants. Many such stems later rupture longitudinally, thus exposing to desiccation risk sometimes even 2-3 tunnels may be seen in transverse sections of the stem.
- At the places of the pupal chamber, the stem walls become thickened to form galls. The adults emerge by biting holes through these galls. As a result, the stem becomes very weak and breaks down at such places during heavy windssuch plants often lie prostrate on the ground and dry up.

Management of stem weevils:

- Destroy all wild amaranthus plants in the vicinity.
- As soon as an infestation is observed, remove and destroy all the affected plants promptly with grubs

inside.

- Spraying with Neem seed extract 5% (w/v) is helpful to reduce the pest infestation.

Beet webworm, *Poladea recurvalis*

Damage:

- Young caterpillars feed on the epidermis and voraciously feed on the green matter.
- Older ones web the leaves together and feed within.
- Severe attack results in complete skeletonization and drying up of the leaves within a short time.

Management:

- Plough around trees to expose and kill pupae,
- Collect and destroy the caterpillars,
- Conserve the parasitoids such as *Trichogramma, Bracon, Panteles ampoletis*
- Spray azadirachtin 0.03% (300 ppm) @ 1000-2000 ml in 200-400 l of water/acre or azadirachtin 5% W/W neem extract concentrate @ 80 ml in 160 l of water/acre.

Leaf miner: *Iiriomyza huidobrensis*

Damage:

- Maggots produce the serpentine leaf mines, which are usually white with dampened black and dried brown areas.
- Several larvae feeding on a single leaf may produce a secondary blotch like mine, and leaf wilt may occur.

Management:

- Hand-picking and destruction of infested leaves with maggots in the early stages may effectively reduce population built-up.
- Spray *Azadirachtin* 0.03% (300 ppm) @ 1000 - 2000 ml in 200-400 l of water/acre or *Azadirachtin* 5% W/W Neem extract concentrate @ 80 ml in 160 l of water/acre.

Aphid, *Myzus persicae*

Damage:

- The nymphs and adults cause the damage both by sucking plant sap, causing yellowing and drying of leaves.
- Severe infestation results in curling of leaves, stunted growth, gradual drying, and death of the plants' tender region.

A B C D

Fig.1: Insects infesting Amaranthus plant
(source: www. majorpestsofamranth)

A: *Pyrgomorpha* sp., B: *Hypolixus nubilosus*, C: *Cletus* sp., D: Webworm infested leaves

- They produce copious amounts of honeydew, which serves as a medium on which sooty mold grows. Sooty mold blackens the leaf and decreases the photosynthetic activity of the plant.
- Seed production is hampered by aphid infestation where it may lead to deformed seeds, decreased flower and seed formation, or reduced seed viability.
- It also transmits many important plant viruses such as such as Potato leaf roll virus (PLRV), Potato virus Y (PVY), Cucumber mosaic virus (CMV) and Pepper veinal mottle virus (PVMV).

Management:

- Destroy the infected plant parts.
- Follow clean cultivation.
- Conserve the Parasitoid, *i.e.*, *Phidius colemani* and Predators, *i.e.*, syrphid/hoverflies, green lacewings (*Allada basalis* and *Chrysoperla carnea*, predatory coccinellids (*Tethorus punctillum*, etc.
- Spray azadirachtin 5% W/W neem extract concentrate @ 80 ml in 160 l of water/acre.
- Spraying of *erticillium lecanii* @ 0 viable spores/ ml reduce the aphid population.

Amaranthus leaves and stems are commonly eaten after cooking in a manner similar to spinach. There are four main species that are cultivated as vegetables; *Amaranthus cruentus, Amaranthus blitum, Amaranthus dubius* and *Amaranthus tricolor*. Several species, such as *Amaranthus caudentis, Amaranthus cruentis* and *Amaranthus hypochondriacs,* are grown as a grain crop in places such as Mexico, Nepal, and India to produce cereals and snacks. This is the best crop in rainfed areas.

Agroforestry practices for food security and ecosystem services in dryland areas

Antony Joseph Raj

Agroforestry is basically a land use strategy that integrates agriculture and forest production. Agroforestry plays important roles in increasing the sustainability of farming systems, production of fuel wood, production of animal fodder and cash products, and diversification of agricultural products. In India, research on agroforestry is still insufficient in contrast to other countries. Among agroforestry systems, alley cropping, scattered trees, wind breaks, bully plantation and sylvopastoral practices are suitable to the dryland areas. Agroforestry practices for dryland involves plantation of multipurpose trees, adoptation of agri-silvicultural and agri-hoticultural systems, nutrient management and soil conservation etc. Growing trees and crops along with livestock in drylands may help to increase soil health, crop yield, soil micronutrients, adaptation to climate change as well as food, fodder, wood and fibres. Adopting such practices will help to sustain agricultural production as well as in doubling farmers income in semi arid regions.

Globally 40 percent of the land cover area is classified as drylands, which supports 2.5 billion people. It is reported that 90 percent of drylands are in developing countries, and 10 percent of drylands are severely degraded and need immediate attention. The potential of trees to bring improvements in nutrition, income, housing, health, energy needs, and environmental sustainability in the dryland areas has guided ICRAF's mission, with trees being the principal component of an "evergreen agriculture." Within the array of benefits brought by trees, an essential element is trees' positive effect on soil properties and, consequently, benefits for crops. In this scenario, agroforestry systems have been indicated as one of the more promising alternatives to achieve more sustainable agriculture, especially for poverty reduction, food security, and maintaining environmental services. Trees and woody vegetation are widely incorporated in various dryland agroforestry systems practiced in agricultural landscapes worldwide.

Agroforestry practices in dryland areas

Agroforestry is a land management system that seems to be suitable for the fragile ecosystems of the developing world. It combines the protective characteristics of forestry with the productive attributes of both forestry and agriculture. Agroforestry is a new name for the old practice of growing trees on farmland. Farmers have been practicing agroforestry for thousands of years by combining trees with crops or animals. When land is scarce, or soil has low fertility or is sensitive to erosion, agroforestry techniques offer considerable benefits for long-term agricultural sustainability. Agroforestry in drylands can help to make small farms more productive by increasing family income. Farmers have integrated trees in their rainfed farming systems for centuries. About 1.2 billion people of the world rely on agroforestry practices that help sustain agricultural productivity and generate income and agroforestry also plays a crucial role in the lives of the world's poorest people.

Dryland agroforestry systems are designed to produce a range of productive benefits, including food, fodder, fuelwood, fibres, wood, pole, etc. as well as protective services such as reducing soil and water erosion; improving soil fertility status; improving water quality and yield, flood control, biodiversity conservation, microclimate modification, carbon sequestration, climate change mitigation, aesthetic value, etc. Agroforestry systems in drylands take advantage of trees for many uses to hold the soil, increase fertility through

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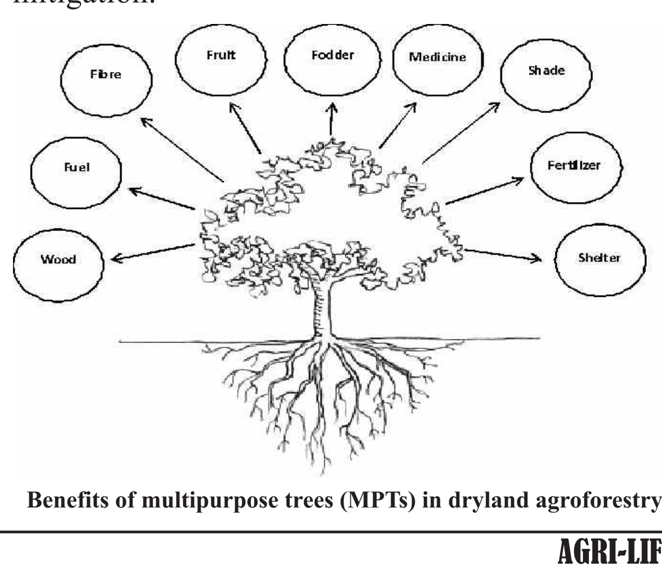
nitrogen fixation, or to bring minerals from deep in the soil and deposit them by leaf-fall, to provide shade, construction materials, foods, and fuel. Agroforestry practices are intentional combinations of trees with crops and/or livestock that involve intensive management of the interactions between the components as an integrated agroecosystem. These four key criteria - intentional, intensive, interactive, and integrated - are the essence of agroforestry and distinguish it from other farming or forestry practices. To be called agroforestry, a land-use practice must satisfy all of the following four criteria/ four "I" words.

Agroforestry is an ancient land use practice and modern science involving the deliberate management of trees on farms and surrounding landscapes. Dryland agroforestry systems vary significantly in tree species mix, complexity, configuration, and input requirements, producing a wide range of products and services to benefit the rural community in dryland areas and drought-affected zones. With appropriate technical and institutional support, the practice of agroforestry in drylands can contribute to rural food and health systems and help to buffer households against health and nutrition shocks. By combining the strengths of agriculture and forestry, agroforestry opens up promising new prospects for rural communities' future in dryland areas.

Multipurpose trees (MPTs) in dryland agroforestry

Agroforestry is the intentional integration of woody plants into crop and livestock systems to improve soil, water, air quality, and biodiversity while supporting sustainable food, feed, fibre, and energy production. One of the key components in the dryland agroforestry system is the multipurpose trees (MPTs). MPTs are woody perennials that are deliberately kept or grown in a land-use system to produce multipurpose products and benefits. Multipurpose trees (MPTs) are referred to as mean "tree species that are grown to provide more than one significant crop or function on the farm. On small farms, this can often mean, for instance, that the farmer uses both wood and leaves from the same tree." The trees and woody plants in a dryland agroforestry system are not necessarily planted. Instead, natural regeneration of trees may be protected, or mature trees may be deliberately left in the fields or pastures.

In dryland agroforestry, particular attention is placed on multipurpose trees and perennial shrubs. The most important of these trees are legumes because of their ability to fix nitrogen and make it available to other plants. Considerable knowledge on properties of trees is necessary to incorporate them in dryland agroforestry systems such as size and form of the canopy, root system, climatic adaptation of the species, adaptation to various soils and stresses, and suitability for various agroforestry practices. The trees and woody plants can be planted in dryland agroforestry in different ways *viz.* individual trees, scattered trees, lines of trees with crops, strips of trees along contour and waterways, boundary lines, living fences, windbreaks, shelterbelts, terrace planting on hills, wood lots, etc. The role of trees and woody vegetation in dryland agroforestry includes- a source of fruits, nuts, and edible leaves to humans; source of fodder to livestock animals; source of non-edible materials including resin, tannin, insecticides, and medicinal products; source of construction materials, posts, lumber, and thatching; source of fuel; beautification and shade; soil conservation and improvement of soil fertility; water quality improvement; climate amelioration; carbon sequestration and climate change mitigation.



Benefits of multipurpose trees (MPTs) in dryland agroforestry

Agroforestry for ensuring food and nutritional security in drought-affected areas

Agroforestry is one of the best opportunities and has great potential to increase food production in developing and poor countries. Agroforestry is an important option to provide food security to smallholding poor and marginal farmers in the dryland areas. If adequately implemented through national measures, it can ameliorate food insecurity in the arid and semi-arid zones of a country on a larger scale. The services provided by dryland agroforestry practices to rural livelihoods and conservation of biodiversity have attracted wide attention. It applies scientific principles to find practical solutions to natural resource management and agricultural production problems and subsequently supports improving the vast rural population's food security in dryland areas. There are various agroforestry practices in the dryland areas made up of several types of products, which are both subsistence and income generating, help the farmers meet their basic needs and minimize the risk of the production systems and total failure. The Agrisilvicultural system (Moringa Trees + Agricultural crops) is one of them. There is a concurrent production of agricultural crops and trees in the same land either simultaneously or alternately. The agrisilviculture systems aim to produce enough foodgrains, timber, fodder, firewood, and other products in dryland areas. The Agrihorticultural system (Fruit trees + Agricultural crops) also ensures food and nutritional security.

Moringa trees based agrisilvicultural system for food and nutritional security

Moreover, planting drought-tolerant multipurpose trees in the homegardens produces diverse products (various fruits and fodder), which are available year-round and contribute to food security during the "lean" seasons and ensure food diversity. The mixed tree-gardens represent a substantial unexploited potential for enhancing the productivity and profitability of dryland areas. Higher soil organic matter and available nutrients in tree-based agroecosystems can also increase yields in smallholder farming systems in dryland areas. A study from Nepal on the impact of agroforestry on soil fertility and farm income showed that agroforestry intervention nearly doubled farm income per hectare from USD 800 to USD 1580. A similar report of increased crop production and generating additional income to the rural people are reported in Malawi of South Africa by improving soil condition through the intervention of agroforestry practice. Agroforestry adoption has shown positive impacts on farmers' livelihoods in Malawi, Mozambique, and Zambia, increasing crop yields, increased income, and increased savings in a change of wealth and soil improvement.

The tree components of the dryland agroforestry system can contribute to increased food availability at the household level through four significant pathways. First, the contribution of fodder supplement can increase the productivity of livestock. Higher productivity can result in greater food availability and/or higher incomes. Second, green leaf manure harvested and ploughed *in situ* and tree-crop-soil interaction can increase soil fertility and improve food and non-food crops' improved productivity. Higher soil fertility is likely to increase the food/cash crop productivity and household income that will, in turn, contribute to food availability. Third, fruits and vegetables harvested from the tree component of agroforestry will directly contribute to improved dietary quality and micronutrient consumption and indirectly contribute through the sale of these items to the market for income to purchase food. Finally, the non-food tree outputs such as timber for housing and firewood for fuel contribute to income that can be used to acquire food. Domestication of forest fruit trees and other species are grown in dryland agroforestry systems offers significant opportunity for livelihood improvement through nutritional and economic security of the poor in the tropics.

Citrus trees based agrihorticultural system for food security

Agroforestry for soil quality improvement

The presence of trees in the dryland ecosystem can influence the nutrient content of the soil via its impacts on the soil structure and the soil biology and also due to the particular functioning of trees. There are three levels of interactions. First of all, trees can be providers of new inputs for the nutrient cycle. For instance, tree canopies collect atmospheric depositions that are incorporated into the soil when the leaves fall. Also, deep roots of the trees can capture nutrients and minerals from the rock and the subsoil and pump it to the canopy so that it is an input in the nutrient cycle. Certain tree species associate with nitrogen-fixing or phosphorus-solubilizing mycorrhizal or rhizospheric organisms and make these nutrients available for the plants of the entire ecosystem. Secondly, trees can be active drivers in the nutrient cycling processes. Trees help promote the nitrogen cycle in agroforestry. Nitrogen is supplied to the topsoil by the fertilizer and/or the manure applied in the alleys, the biological fixation from the atmosphere (N-fixing tree species), and the mineralization of organic matter (which is also influenced by the trees) (notably by root exudates, improved soil conditions, and root turnover). Trees help avoid the nutrient leaching and seepages thanks to their "safety net," *i.e.*, their vast root system that can uptake nutrients in the deeper soil layers where crop roots cannot take. By actively capturing leached nutrients and pumping them back to the canopy and then to the topsoil, the trees decrease the erosion and nutrient losses, maintain the nutrient pool and the soil fertility, and improve the efficiency of nutrient use the agroecosystems. Finally, some tree roles in the nutrient cycle can be enhanced by human intervention. Litterfall and pruning by-products are major organic matter inputs, and their decomposition releases nutrients in the topsoil.

Trees play the essential and most dominant roles in dryland agroforestry systems. Better emphasis is given to trees and woody plants that are indigenous in nature and can fix atmospheric nitrogen-selection and management of MPTs influence any dryland agroforestry system's success. The nitrogen-fixing trees (NFTs), besides their nitrogen-fixing ability, provide protein-rich foliage that can be used for fodder and green manuring. More than 650 tree species are known to fix nitrogen and can be incorporated in agroforestry systems. The most important nitrogen-fixing fertilizer trees used in dryland agroforestry are *Faidherbia albida, Leucaena leucocephala, Acacia nilotica*, *Acacia tortilis*, *Acacia Senegal*, *Acacia auriculiformis*, *Acacia cyanophyll,* many other *Acacia* spp., *Prosopis cineraria*, *Prosopis juliflora*, *Inga jinicuil*, *Sesbania* spp., *Calliandra calothyrsus, Erythrina* spp., *Pithecellobium dulce*, *Flemingia* spp., *Cassia siamea, Albizia amara*, *Albizia lebbeck*, *Albizia procera*, *Albizia saman*, *Dalbergia sissoo*. *Casuarina equisetifolia* has found extensive use to consolidate sandy coastal soils and fix atmospheric nitrogen.

Agroforestry for biodiversity conservation

Agroforestry is identified as integrated land-use system, which enhances plant diversity and reduces habitat loss and fragmentation. Agroforestry provides a way for several combinations of trees and crops of valuable species for the human population, which enriches the area's biodiversity. Agroforestry is increasingly being acknowledged as an integrated land use that can directly enhance biodiversity and contribute to the conservation of landscape biodiversity. Biodiversity plays a vital role in sustaining human life and the health of our planet. The role of agroforestry in conserving biodiversity includes: agroforestry provides habitat for species that can tolerate a certain level of disturbance; agroforestry helps to preserve germplasm of sensitive species; agroforestry helps to reduce the rates of conversion of natural habitat by providing a more productive, sustainable alternative to traditional agricultural systems that may involve clearing natural habitats; agroforestry provides connectivity by creating corridors between habitat remnants which may support the integrity of these remnants and the conservation of area-sensitive floral and faunal species; and agroforestry helps to conserve biological diversity by providing other ecosystem services such as erosion control and water recharge, thereby preventing the degradation and loss of surrounding habitat.

By their very nature, agroforestry systems are more diverse than monocultures of crops and livestock; this increase in 'planned' biodiversity, *i.e.*, the components are chosen by the farmer, increases the 'associated' biodiversity, *i.e.*, the wild plants and animals occurring on the farmland. Agroforestry systems support floral and faunal assemblages that can be as species-rich, abundant, and diverse as forests, but often with modified species compositions that include non-forest species. Thus, in agroforestry, the integration of trees and livestock on farmland increases biodiversity; this varies with land management practices, cropping patterns, and the arrangement of different components. These agroforestry components introduce another kind of biodiversity in soil flora and fauna, herbivores, carnivores, decomposers, etc.

Agroforestry for carbon sequestration and climate change mitigation

Agroforestry is an appealing option for sequestering carbon on agricultural lands because it can sequester significant amounts of carbon while leaving the bulk of the land in agricultural production. These practices represent a category of conservation/ production activities that can sequester large amounts of carbon while providing a multitude of additional benefits. Simultaneously, it can help the landowners and society address many other issues such as economic diversification, biodiversity, and water quality. The perennial agroforestry systems, which allow full tree growth and have an essential woody component, store considerable carbon in the living biomass. Agroforestry attracted particular attention as a carbon sequestration strategy following its recognition as a carbon sequestration activity under the afforestation and reforestation (A&R) activities of the Kyoto Protocol. Agroforestry practices can be a better climate change mitigation option than the ocean and other terrestrial options because of vast production and protective benefits. As reported by PKR Nair, carbon-sequestration potentials vary from 0.29 metric tons of carbon per hectare per year in fodder banks (trees and shrubs grown as food for livestock) of the West African Sahel to 15.21 metric tons of carbon per hectare per year in mixed-species stands of Puerto Rico.

According to the Intergovernmental Panel on Climate Change (IPCC), agroforestry offers significant opportunities to create synergies between adaptation and mitigation actions with a technical mitigation potential of 1.1-2.2 Pg C terrestrial ecosystems over the next 50 years. Additionally, 630 million ha of unproductive croplands and grasslands could be converted to agroforestry representing a carbon sequestration potential of 0.586 Tg C/yr by 2040. This total carbon storage in the aboveground and belowground biomass in an agroforestry system is generally much higher than the land use without trees under comparable conditions. Agroforestry can give the landowner the biggest net gain of carbon per unit area typically without compromising agricultural activity. Agroforestry represents a significant opportunity for sequestering carbon on agricultural lands in that a substantial proportion of the carbon is sequestered in woody biomass, thus creating a system that sequesters a large amount of carbon per unit area and for a longer duration than many other practices.

Agroforestry for climate change adaptation

Climate change is expected to decrease agricultural productivity in the developing world by 10-20 percent over the next 40 years. Under the climate change scenario, agroforestry will help overcome climate change vulnerability and increase rural people's resilience. Agroforestry has been proposed as a potential strategy for helping subsistence farmers reduce their vulnerability to climate change. Agroforestry trees are considered to be less sensitive to climate-related shocks such as floods and droughts due to their deep root systems. Agroforestry techniques also include using and selling tree crops such as fuelwood, fruit, and timber. Agroforestry trees can also reduce soil erosion in agricultural lands by providing long-term vegetation cover. Many research studies have confirmed the specific role of agroforestry techniques, which can play a vital role in helping farmers to reduce their vulnerability to climate change. In a nutshell, agroforestry improves farmer well-being by improving farm productivity and incomes under a climate change scenario.

Agroforestry has been brought from the realm of indigenous knowledge into the forefront of agricultural research less than four decades ago. It has been promoted widely as a sustainability-enhancing practice that combines the best attributes of forestry and agriculture. Growing trees and crops and livestock in the dryland areas has been postulated to enhance crop yields, conserve soil, and recycle nutrients while producing fuelwood, fodder, fruit, and timber. Mixing trees, crops, and/or animals can take on many shapes and forms in the dryland agroforestry systems. Dryland agroforestry is essentially meant for smallholder farmers who live partially from subsistence agriculture. Still, there are also agroforestry practices that can be used in intensive land-use systems on large-scale farms.

While applied research efforts have raised agroforestry awareness in the arid and semi-arid zones and helped institutionalize dryland agroforestry in national programmes worldwide, the need for a critical, science-based approach gradually emerged. Agroforestry is a field of study which involves the combined application of ecology, economics, agronomy, forestry, soil science, animal science, tree genetics, biometrics, anthropology, and other applied sciences. One of the challenges of agroforestry is to create conditions for an efficient multidisciplinarity. Agroforestry involves all the above disciplines to include trees in agricultural lands. Hence agricultural and forestry institutions should be closely involved in conducting coordinated research to develop dryland agroforestry technologies. In short, foresters and agronomists must work together to develop promising agroforestry innovations to benefit the rural community in the drylands.

The farmer works the soil, The agriculturist works the farmer.

- Eugene F. Ware

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Earth is here so kind, that just tickle her with a hoe and she laughs with a harvest.

- Douglas Jerrold

Synergies of perennial farming to mitigate water scarcity in agro-ecosystems

Manmohan J. Dobriyal, Jahangeer A. Bhat and Pavan Kumar

Rainfed areas are extremely diverse, ranging from resource-rich areas with valuable agricultural potential to resource-poor areas with significantly more limited potential. Life is fragile in the drylands and people have a considerably lower socio-economic status. Most of these people rely on forests and other forested lands, grasslands and trees on farms in order to meet basic needs for food, medicine, shelter, cooking, heating, wood, livestock feed and livelihoods. Perennial plants, especially trees play an imperative role in the terrestrial ecosystems and deliver a series of products and services to rural and urban societies. A more sustainable approach to combat drought episodes is to increase soil water storage and total green water production for agroecosystems. Farming practices that encourage continuous perennial green and living cover, also improves water management, in comparison to annual crop systems. Promoting vegetative cover for the protection of soil and moisture will help to preserve and stabilise habitats to encourage resilient farming systems to mitigate risk during severe weather events. Farmer-managed natural regeneration (FMNR) is regarded as one of the most promising strategies in dryland systems to restore degraded agricultural ecosystems. For individual farms, as well as for wider community and ecosystem protection, tree farming land use is centered on agroecological principles and provides higher water resistance. Therefore, in order to preserve agricultural productivity, tree-based farming must be promoted in all categories of farms as per the national agroforestry policy, 2014. Tree farming in water stressed areas can play an important role in increasing the overall farm productivity to support the food and nutritional security. Cross-cutting initiatives that involve improvements in land use in terms of integrating tree-based farming, and also buffer strips to sustain the development of woodlots around and along agroecosystems needs to be addressed with proper planning. Such approaches and practices can have major synergies with general environmental conservation and are central to sustainable agriculture, including biodiversity, the protection of water quality and food security.

The highest upward record of agricultural production over the years has taken place under irrigated conditions. There are limited prospects for the continued extension of irrigated areas; however, Indian policy initiators are increasingly focusing on rainfed or un-irrigated agriculture to assist and meet the rising food demands anticipated over the next few decades. Rainfed areas are extremely diverse, ranging from resource-rich areas with valuable agricultural potential to resource-poor areas with significantly more limited potential. Some resource-rich rainfed regions are potentially extremely fertile and have already experienced ubiquitous adoption of better quality seeds.

Life is fragile in the drylands, and people in the drylands have a considerably lower socio-economic status than people in many other areas. Around 41 percent of the Earth's land surface is occupied by drylands and characterised by a lack of water. The estimated two billion people living in the drylands, almost 90% are in developing countries. Most of these people rely on forests and other forested lands, grasslands, and trees on farms to meet basic needs for food, medicine, shelter, cooking, heating, wood, livestock feed, and income.Already one-third (on

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average) below the threshold for minimum human well-being and sustainable growth, water supply in drylands is projected to decrease further due to climate and land-use changes. The most vulnerable to food shortages would be disadvantaged people living in areas far from public services and markets and relying on marginal natural resource bases already leading to forced migration.

Perennial plants,especially trees, play an imperative role in the terrestrial ecosystems and deliver a series of products and services to rural and urban societies. Although important for food production, land conversion from natural to controlled systems continues to occur at high rates. Whenever the need arises for any developmental works, the trees are the first target, as trees are cut for food, infrastructure, and other development activities. Considering the benefits that trees provide, all these circumstances are best sustained by integrating woody perennials into agricultural systems. The addition of perennial components in the form of tree planting has drought tolerance and can withstand the aberrations of monsoon along withimparting stability to agriculture production. While selecting perennial trees for farms, the competition level between the trees and crops for soil and water should be minimal. Because of differences in the rooting depths, the combination of annual crops and trees can increase biomass output and as the general understanding that trees are less prone than annual crops to extreme soil and climatic conditions. The vital point to understand is that even if there is a crop failure, trees will ensure some returns, thus having an optional value even in crises.

Hydrological balance through perennial farming in dry regions

Drylands, arid lands, and rainfed regions are terms used interchangeably to designate lands not irrigated by canals or tubewells, where agriculture relies solely on rainfall. However, drylands are generally characterized as sub-humid arid, semi-arid or drylands receiving annual precipitation of less than 500 mm with an index of aridity between 0.05 and 0.653 (the aridity index is the ratio of Precipitation / Potential Evapotranspiration).

The key issues facing the production and dissemination of emerging technologies concentrate on soil and water management. Indian soil types vary widely from black clay soils (vertisols) that are moisture-retentive to sandy red soils (alfisols) that retain very little moisture. Nowadays, with technological approaches such as irrigation and tile drainage, many countries are overcoming their water scarcity in the agricultural system, which may not be sustainable in the long term. A more sustainable approach to combat drought episodes is to increase soil water storage and total green water production for agroecosystems. Farming practices that encourage continuous green and living cover, such as perennial trees as cover crops, will improve water management compared to annual crop systems. Such practices preserve living roots in agricultural systems throughout the year and provide an approach to agroecosystem design that mimics perennial native vegetation's ecological dynamics.

Tree-based farming and water productivity

Rising global concern is the urgent need to improve water efficiency. For efficient and sustainable use of land and water, tree-based farming offers a promising choice. The combination of trees with productive agricultural practices provides opportunities to counter the negative effects on the environment caused by deforestation and intensive cropping systems.Opportunities to use tree farming to stop or reverse land destruction are also available. In rain-fed agricultural systems, the availability of water in the soil derives mainly from infiltration after precipitation. However, while biomass production is often restricted by the limited availability of water in annual cropping systems, residual water often remains in the soil after harvesting, and off-season precipitation goes unused. A large proportion of the annual rainfall may be lost via evaporation from the soil surface to horizons below the rooting zone.

In systems where annual crops provide partial ground cover during the early stages of the rainy season and may never reach maximum ground cover, soil evaporation may account for 30-60 percent of annual rainfall. Researchers have found that only 6-16 percent of the total rainfall obtained was used for transpiration from millet crops on a watershed in Niger. Most of the rest were lost by evaporation (40 percent) or deep drainage (33-40 percent). Similarly, sorghum/pigeonpea intercrops were used in India for only 41 percent of the annual rainfall, while the remainder was lost as runoff (26 percent) or soil evaporation and deep drainage (33 percent); 20 percent or 152 mm of the annual precipitation was received outside the cropping season.

Significant potential exists for the production of improved agricultural technology to exploit these untapped deposits, although this could, in certain cases, limit the recharge of wells and aquifers. Studies from Hyderabad, India, recorded that hedgerow sole Leucaena plants extracted more of the available soil water than sole sorghum and pigeon pea crops or intercrops. More water was obtained from widely spaced alley crops (4.4 m between hedges) than from single Leucaena, implying that the agroforestry system was most effective in extracting the available water.

Soil and moisture conservation through the inclusion of perennials

Promoting vegetative cover to protect soil and moisture will help preserve and stabilise habitats and encourage resilient cropping and farming systems to mitigate risk during severe weather events. Trees can surge the crop produce by safeguarding soil moisture through mulching, and it has been observed by the researchers that moisture availability is higher under tree cover. Several studies have stated and suggested that tree-based farming improves groundwater quality by reducing pollution caused by the leaching of nutrients usually applied to the cropping system. The possibilities of tree-based farming (agroforestry) have been observed by several studies and reports of an increase in infiltration characteristics of the soil and reductions of runoff. Thus soil moisture content and groundwater level/quality can be sustained through perennial crop farming, which will increase the water availability and food security guarantee. Trees on farmlands and peripheral areas are also responsible for the recharge of water through their root system, not just in the sub-surface but also in the deeper layers.

Soil erosion in the rainy season is a major problem, including landslides in hills. The rate of soil loss depends heavily on the form of soil, its initial depth, and the period during which the erosion rate is maintained. Although evaluating the aggregate effect of erosion on production, it is important to understand the short and long-term impacts of erosion. Declining yields associated with soil erosion can be reversed by planting trees along or around the crop farms. Approaches to land and soil management to tackle soil erosion, prevent soil organic matter depletion, sequester soil carbon, and enhance water retention are crucial to the long-term sustainability of agriculture and healthy habitats and should be promoted at all levels.

Promotion of perennial cultivation along with trees or shrubs in degraded land is one of the proven very economic technological interventions in the restoration of these lands. The phase-wise restoration process is ultimately settled with commercial crop cultivation. Further utilization of land as per land capability classification in group IV to group VII is possible ecologically suitable and economical for livelihoods option generation with perennial crops and trees in water scare areas. In the critical season of summer, the trees on the agricultural landscape provide solace to the farmer in dry areas for all agrarian activities, including livestock management. Soil and water are two important natural resource components that are essential to be stabilised for sustenance with an ecological approach.

Bamboo, Leucaena- Gliricidia hedges with Mucuna intercrop, RLBCAU, Jhansi


Established Bamboo -Jackbean intercropping), RLBCAU, Jhansi

Restoration of degraded area with physical and biological measures

The way forward and future prospects

Therefore, immediate action is required to enhance the management and conservation of dry land. Such intervention includes a thorough understanding of dryland complexity, position, functions, and context-specific approaches adapted to the particular conditions of drylands. Globally, populations, especially in developing countries, are affected by land degradation due to high population pressure, dependence on charcoal and wood resources as the key energy sources, and livestock overgrazing. Subsistence farmers face a decline in food security due to soil quality losses and a decrease in land productivity. Integrating trees on farms and pasture land is also a good restoration technique. Research has shown that productivity can be improved by tree-based farming.

Farmer-managed natural regeneration (FMNR) is regarded as one of the most promising strategies in dryland systems to restore degraded agricultural ecosystems. Under FMNR, by cultivating spontaneous/natural woody regeneration, farmers actively revegetate their fields while holding crop production as their priority. In Niger, more recently also in Burkina Faso, Mali, Senegal, and Ethiopia (African continent), FMNR has been successful, demonstrating that it can reverse tree cover loss diversity in dryland systems. These examples have led to high expectations for FMNR as a low-cost and successful restoration tool for degraded arable drylands. They are currently being promoted across regions in Africa, Asia, and the Pacific.

Diversity at both the national and local levels has implications for strategies for agricultural


Initiation of planned NTFP multi-tier vegetation trees for fodder and shelterin dry areas

production. At the national level, there is a need to differentiate between regions based on their agricultural growth constraints. To serve as an instrument for the planning of agricultural research and other public expenditure, this involves developing a typology of rainfed agriculture that would integrate both agroecological and socio-economic variables. For individual farms and wider community and ecosystem protection, tree farming land use is centered on agroecological principles and provides higher water resistance. Therefore, to preserve agricultural productivity, tree-based farming must be promoted in all categories of farms as per the national agroforestry policy, 2014.The priority setting for minimum trees on the farm or other non-forested lands in dry areas should be advocated as policy guidelines by the government. The perennial crop cultivation in dry areas is linked with main farming practices like conservation agriculture or organic farming for the region's sustenance.

Tree farming in water-stressed areas can play an important role in increasing overall farm productivity. Its contribution is even more prominent in the rain-fed and arid regions to support food and nutritional security. With the increasing global population, a higher level of farm productivity and better environmental services is imperative. It is expected that, in the changing global scenario, planting trees along with cultivable crops would provide sufficient options to increase the productivity and profitability of agricultural systems in different land-use systems. Once again, recent climate change and monoculture adversities have paved the way for introducing trees into agriculture and have been recognized as one of the most adaptive land-use technologies to tackle climate change. Trees offer countless direct and indirect benefits, such as food and nutritional protection, fodder, wood, fuel, energy, and NTFPs, fulfilling farmers' subsistence and commercial requirements.

The future of modern agriculture, which aims at creating sustainable livelihoods, nutritional security, and food production in the pattern of land use, is, therefore, tree-based agriculture. Cross-cutting initiatives involve improvements in land use in terms of integrating tree-based farming and buffer strips to sustain the development of woodlots around and along agroecosystems. Such approaches and practices can have major synergies with general environmental conservation and are central to sustainable agriculture, including biodiversity, the protection of water quality, and food security, in terms of increased resource quality, cost savings, and potentially greater economic stability with other benefits to farmers.

Agriculture was the first occupation of man, and as it embraces the whole earth, it is the foundation of all other industries.

- Edward W. Stewart

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If farm ecology and economics go wrong, nothing else will go right in agriculture.

If agriculture goes wrong, nothing else will have a chance to go right in the country.

- M. S. Swaminathan

Production technology of Ivy gourd under rain-fed & dry-land condition of Bundelkhand region

Gaurav KumarAhirwar[1], Harpal Singh[2] and Amit Tomar[3]

Ivy gourd serves the purpose of being grown under rain-fed and dry-land condition as it is resistant to drought in the Bundelkhand region. Drought stress triggers drought tolerance mechanisms involving certain morphological, physiological, and biochemical traits in vegetables, which are considered adaptive. However, the commercial scale is modest, with areas over 1 acre, the average area under commercial vegetable-cultivation per cultivating household ranges from 0.3 to 0.7 acres. Ivy gourd traits should be investigated thoroughly to serve as screening tools in developing drought-resistant varieties with more significant potential to maximize the use of stored soil water and increased economic yield per unit water use in the

Moisture stress is one of the most significant environmental factors reducing yield in arid and semi-arid crops. Drought is often accompanied by relatively high temperatures, which promote evapotranspiration (ET) and affects photosynthetic kinetics, thus intensifying the consequences of drought and further reducing crop yield. About two-thirds of India's geographical area, the Bundelkhand region receives low rainfall (less than 1000 mm), characterized by uneven and erratic distribution. Maximum rain (about 90%) is received during the southwest monsoon period from June to September. Relative humidity exceeds 87% in August. The year's driest part is the summer season when relative humidity is less than 35%. Out of the net sown area of 140 million hectares, about 68% is reported to be vulnerable to drought stress, and about 50% of such vulnerable regions are classified as 'severe. Being succulent in nature, vegetables are sensitive to drought stress, particularly during the flowering to the seed development stage.

Introduction of Ivy gourd farming

Ivy gourd, *Coccinia grandis* (L)Voigt, is commonly a tropical dioecious, climbing perennial plant having small (4-5 cm long and 1-2 cm in diameter) ovoid or elliptical fruits. The Ivy gourd is a vine. The fruits are smooth and bright green with stripes that become scarlet red on ripening. The roots are long and tuberous. The leaves have five lobes with a serrated margin. It grows in the tropical regions mostly. Ivy Gourd is also known as Baby Watermelon, little gourd, gentlemen's toes, and popularly known as "Tindora/Tondli/Kundru" in India.

The ivy gourd is cultivated in India. This vegetable is widely grown in southern, eastern, and western regions in states like Karnataka, Tamil Nadu, Kerala, Maharashtra, Andhra Pradesh, Gujarat, Telangana, and West Bengal. And countries like tropical Africa, Malaysia, and other southeast Asian countries, &China. This vine has aggressive climbing properties and spreads quickly over fences, trees, shrubs & other supports. Proper cultivation techniques are available for the suitable farming of ivy gourd.

Biosystematics

The genus Coccinia Wight and Arn. belong to the subtribe Benincasinae (Ser) *C. Jeffr*, tribe Benincaseae Ser., sub-family Cucurbitoideae and family Cucurbitaceae. It has about 30 species, occurring mostly in Africa. Only one species, *Coccinia grandis* (L.) Voigt.is cultivated. It is a dioecious perennial found naturally in India and tropical Africa. Amonoecious species is cultivated in Ghana, and the species *C. abyssinica* is grown in Ethiopia for its edible tuberous roots. In India, *Coccinia grandis* (L.)Voigt (*Coccinia indica* Wight

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and Arn.) is distributed in northern plains and Tarai regions extending to the peninsular region.

Genetics and breeding

There are no reports on the genetics and breeding of ivy gourd. Most of the present-day cultivar of ivy gourd has been developed by farmers as clonal selections, mainly from seedling progenies or spontaneous mutations. The fruits of the different varieties vary in shape and size, stripe pattern. There are also few types in which plants with male flowers are absent, and the fruits produced on the female plants are parthenocarpic. Some types having bitter fruits, not suitable for consumption, are found occasionally.

Nutritional and medicinal value of ivy gourd

- For people looking to reduce fat from their body.
- Help prevent obesity
- Those suffering from respiratory issues should take ivy gourd.
- The Ivy gourd can help to control blood sugar levels.
- It reduces fatigue from the body as it consists of 1.4mg of Iron, 17.50%.
- It protects the nervous system.
- It increases the metabolism of the body and thus reduces fat.
- It can be very beneficial for persons with respiratory problems.
- Diabetic patients may take it.
- Potassium in ivy gourd helps to maintain a regular flow of blood and also keeps the heart healthy.
- Ivy gourd contains laxative properties.
- It is a good source of Vitamin C.
- Ivy gourd is rich in Potassium.
- Ivy gourd possesses curative properties for asthma, jaundice, bronchitis & skin problems like leprosy, scabies, and psoriasis.

Propagation in Ivy gourd farming

Ivy gourd is propagating through seeds. The seeds must be selected properly. Only healthy seeds that are disease-free must be chosen for sowing. Seed propagation takes a longer time to germinate and mature. Therefore, ivy gourd is also propagated through vegetative methods such a by cuttings. The cuttings are raised in nurseries.

Planting and transplanting in ivy gourd farming

Mostly planting starts before the rainy season like June to July or in the spring season like February to March. The plant vines should be supported by 2-meter bamboo sticks. When they are suitable for planting, they can be transplanted to the main field. Healthy pants and cuttings must be used for vegetative propagation. For transplanting, pits must be dug in the main area. The pits must be exposed to the sunlight for about a month. fter that, it must be filled with farmyard manure and topsoil. The cuttings must be planted in the pits and water immediately. The seeds can be directly planted in the main field or can be transplanted to the main field from the nurseries. The seeds usualy take 3-4 weeks to germinate. In nurseries, they are grown under control conditions.

Mostly there are two types like Striped Tindora and Non-Striped Tindora. Other high yielding improved varieties of Ivy gourd in India are Sulabha, Indira Kundru-5 and Indira Kundru-35.

Growing requirement in ivy gourd farming

The ivy gourd is basically a crop of tropical climates. Peak seasons of fruiting are the rainy season and summer. The ideal temperature range of 20 to 32^{o}C is best for its growth, quality, and good yield. The soil must be well-drained, fertile and rich in organic matter. For Tindora farming, the soil must be well aerated, with the pH must not be too high or low. The soil ph of 6.0-6.5 is best suited for ths crop. Ploughing makes the soil texture smooth. Farmyard manure must be mixed with the soil after the last ploughing. Drainage channels must be made in the field.

Irrigation

The ivy gourd plants require irrigation at very young stage and just after plantation. During the hot summer season, it needs light irrigation. Drip irrigation is beneficial to maintain adequate moisture during the flowering stage. In winter, it requires less irigation at the surface level to retain moisture.

Fertilizers and nutrition requirements in ivy gourd farming

About 20 tonnes of FYM are applied at the time of basin preparation and planting. The fertilizer requirement is 60-80 kg N, 40-60 kg P, and 40 kg/hectare. Both manures and fertilizers are applied in the year before fruiting starts. The plants start fruiting in 10-12 weeks after planting. The vines are pruned back after the fruiting is completed, leaving 60-75cm long vines. In north India, plants are pruned twice a year. In September and April, about 8-10mm thick shoots are pruned back two buds. Every year ater pruning, about 3-5 kg FYM is applied to each plant. Weeding and light hoeing is done during the early stages of vine growth.

Field

The flowering starts after the 50-60 days of planting. The average yield is about 10-15 tonnes/hectare.

Storage/Harvest

The ivy gourd is mainly harvested for fruits and vines. For vines, the plants must be picked when the leaves are fully mature. The fruits are eaten tender. So, the fruits must be harvested before they reach maturity. The Tindora plant starts flowering after two months of planting. The average yield of 12 to 15 tons per hectare can be obtained with good farm management practices. They can be stored under proper storage conditions. After that, they can be put in boxes or cartons and sold in the market. The fruits must be individually cut from the vines. The ivy gourd vines and leaves must be sold fresh in the market. The immature fruits after harvesting can be stored at room temperature for about a week.

Pest and disease in ivy gourd

Aphids, whiteflies, mites & thrips are the primary pests found in Ivy gourd or Tindora cultivation. Appropriate chemical seed treatment before sowing is also helpful. The insects such as mites, aphids, and caterpillars must be prevented. The fruits must be protected from insects and pests as well. Spraying of pesticides must be done to avoid excessive pest attacks.

Future prospects and scope of Ivy gourd cultivation under the rainfed distribution of Bundelkhand region

There is a vast scope and need for promoting vegetable cultivation as an alternative source of income for small farmers in the Bundelkhand region, for the simple reason that on a per unit of land basis, vegetable cultivation is far more profitable than the cultivation of staple crops. Vegetable cultivation will also help improve the nutritional status of families, mostly women, and children.

- Apart from suitable agro-climatic conditions, an assured supply of water does not necessitate its cultivation.
- Ivy gourd does not require more labor and attention than the cultivation of staple crops as it is a vine crop.
- As most vegetables are highly perishable and have limited shelf life, quick market access, or cold storage facilities, Ivy gourd does not require heavy resources.

Keeping above in mind the above, there is scope for promoting Ivy gourd cultivation as an alternative or even primary source of income for small farmers in particular locations of Bundelkhand regions.

Agriculture is our wisest pursuit, because it will in the end contribute most to real wealth, good morals, and happiness.

- Thomas Jefferson

Earth is here so kind, that just tickle her with a hoe and she laughs with a harvest.

- Douglas Jerrold

Agroforestry for rainfed agriculture and natural resource management

Arvind Bijalwan[*1], Manmohan J. Dobriyal[2] and Tarun Kumar Thakur[3]

Agroforestry is a way of life to the farmers and rural communities where it plays an important role in land-use management, livelihood security and reduction of vulnerability in rain-fed agriculture. It is sustaining the marginal farmers by growing trees and fodder crops including fodder trees with vegetables in marginal lands of many parts of the country. The National Action Plan for Climate Change (NAPCC) under its National mission on sustainable agriculture and Green India mission has exclusively emphasized the agroforestry interventions in India. The root systems of the trees bind the soil, particularly in the ecologically fragile and risk prone areas that create barriers in soil erosion. Agroforestry practices integrating the suitable selection of tree or fruit tree species and other grasses types play a significant role in rehabilitation, reclamation and restoration of such degraded landscape. The silvipasture, hortipasture, silvihortipasture, alley cropping with shrubs, protein banks, energy plantations, catchment treatment and gully plugging by bamboos etc are main agroforestry models suitable for both arid and hill region. In a natural resource system, the carbon sequestration in agroforestry is more liberal in which carbon is stored by the components of the terrestrial ecosystem where trees work as a natural carbon sink for the storage of the large amount of the carbon. In dry regions agroforestry based interventions are directed for amelioration of micro climate, improvement of soil-water regime and economic support to poor people. Peripheral bund planting with trees and shrubs for biofencing and fuel- fodder is drier region is main source of the resource augmentation and conservation. Indigenous Traditional knowledge (ITK) in agroforestry linked with farming quotient (FQ) of the rural agrarian community for soil and water conservation in principle of "Every field should have bund and every bund should have trees". The Agroforestry quotient (AQ) of the farmers and local people from the ancient time is nature friendly to support the natural resource management with inclusion of trees in farming systems and restoration of degraded systems. Therefore visualizing the broader perspective of multifunctional agroforestry it is pertinent that natural resources can be managed efficiently.

Agroforestry is a way of life forthe farmers and rural communities. It plays an important role in land-use management, livelihood security, and vulnerability reduction in rain-fed agriculture. Such adaptations are more probable when combined with traditional resource management systems with indigenous Agroforestry practices. The country is a home of marginal farmers, the food security and livelihood opportunities depend on the performance of small and marginal farmers, but the rain-fed areas are more prone to such farmers where agroforestry play an important role inthe conservation of soil and moisture. Agroforestry proved to be sustaining the marginal farmers by growing trees and fodder crops, including fodder trees with vegetables in marginal lands of many parts of the country. Moreover, in the hot arid and semi-arid areas, tree species such as *Prosopis*, *Albizia, Zizyphus,* and *Acacia*s provided promising returns per unit of land than agriculture alone.

In the subtropical zone of the Himalayas, the Grewia and morus based Agroforestry system is a boon for the farmers. It provides the fodder during the lean periodto supplement the fuel, fiber, and fruits.Agroforestry is gradually gaining momentum and stimulus among the researchers, policymakers, and program executors throughout the world, including India. Considering the Natural Resource Support system, the National Action Plan for Climate Change (NAPCC) under its green India

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mission has exclusively emphasized India's agroforestry interventions. The various agroforestry models such as Boundary plantation (trees on boundary + crops), Block plantation (trees + crops), Alley cropping (shrubs + crops), Agrihorticulture (fruit trees + crops), Agrihortisilviculture (trees + fruit trees + crops), Agrisilvipasture (trees + crops + pasture / animals), Silvipasture (trees + pasture/ animals), Shelterbelts (trees + crops) and Windbreaks (trees +crops) are also a quite promising and boon for the farming communities in water stress areas.

Agroforestry immensely helps in Natural Resource Conservation and Management, one of the much-admired advantages of agroforestry for conserving the soil and maintaining its fertility. In hilly regions, the topography is more prone to soil erosion due to agricultural fields' terraced slopes. As per Narain *et al.,* 1992, it has been observed that even in4% of sloping lands, about 40 Mg/ha soil loss from fallow plots in the western Himalayan region. In the traditional agroforestry systems, trees improve soil fertility, maintain the hydrological balance and stabilize the slopes. The farmers deliberately retain the trees on the bund of their agriculture field to harness the tree benefits on one hand and soil and water conservation.

The root systems of the trees bind the soil, particularly in the ecologically fragile and risk-prone areas that create barriers to soil erosion. Moreover, the debris and leaf fall from the trees in agroforestry make the soil porous and live. The accumulation of organic material is also added to the soil through trees in the agricultural fields, which develop the micro-fauna essential for the decomposition of litter and improve the nutrient cycle. A study conducted by us in the Garhwal Himalayan region observed that the soil moisture% under agroforestry systems was higher than the sole agriculture system, which is considered beneficial for the growth and development of agriculture crops micro-faunal population. The soil moisture% ranged in different existing agroforestry systems varied from 8.66% (Agrisilviculture) in summer to 35.96% (Agrihorticulture) in monsoon season under 0-15 cm of depth and 11.39% (Agrisilviculture) in summer to 31.71% (Agrisilviculture) in monsoon (16-30 cm depth) on different study sites. In pure agriculture crop system, the soil moisture% is slightly lower as compared to agroforestry systems; this is due to the high rate of evaporation of water from the surface of open fields during the summer season, while the reverse trend in the monsoon season has noticed due to prevalence of excessive moisture.

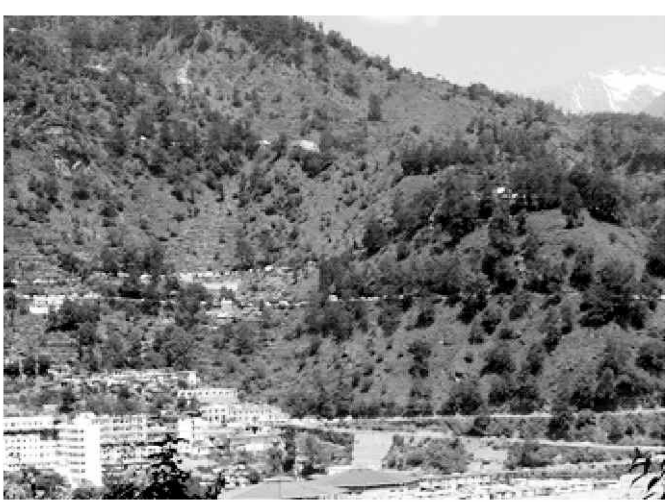
Another area to be restored by agroforestry is mining lands as mining created causes vast land infertility, which is more in the forested regions, where mines have usually done on a large scale. The degraded devastation environment by mining for coal & minerals, quarrying for stones and other materials to

Traditional agroforestry system in Uttarakhand

Vegetables based agroforestry system in Himachal Pradesh

meet industries' demands, is an inevitable part of civilization industrialization. Agroforestry practices integrating the suitable selection of tree species andother grasses types play a significant role in rehabilitating, reclamation, and restoration of such degraded landscape natural resourceful areas affected by mining for organism interactions and dynamics effort. Tree species in a combination of grasses (silvipasture) is an important aspect for speed up the process of restoration in post-mining land use. Where the primary intention is erosion control, fast-growing grasses and legumes are likely to be most suitable. Agroforestry also supports and enhances the overall productivity in agroforestry systems by increasingthe yield of crops and trees, including shrubs and herbs per unit of land in a given time. Compared with the productivity of crops grown under trees, the sole agricultural crop's productivity increases or decreases results that depend on the biophysical, climatic, species, and topographic factors.

In a natural resource system, the carbon sequestration in agroforestry is more liberal in which carbon is stored by the components of the terrestrial ecosystem where trees work as a natural carbon sink for the storage of a large amount of the carbon. Similarly, a large amount of carbon can be stored in soils and vegetation in the terrestrial ecosystem. Thus, with sequestering the carbon, agroforestry also provides many environmental services like biodiversity conservation, soil enrichment, temperature regulation, soil moisture conservation, etc., and subsequently reinstates the environment.



Trees on hill slopes for the conservation of land Resources

Water harvesting pond surrounded by trees in the rural landscape

Agroforestry is a complex system that includes biotic and abiotic components of trees, crops, soil, and water; therefore, it should be considered a sturdy tool for natural resource conservation and management. As per WAC, 2013, the justification for adopting agroforestry has to be emphasized with proper tree crop combinations for different agro-climatic regions of the country with sound management practices. The agroforestry system aims to manage so that the production of preferred commodities and the land piece's productivity may remain tied in increasing trend with improved or new environmentally friendly agroforestry technologies well accepted by the local communities. Consideration of local factors is always important in good management planning;therefore, it is important to include the local facts on the priority level based on analyzing the existing land-use system and resource allocation at the community and household levels.

The sound knowledge of component tree-crop interaction is important as it is a complicated task. Proper silviculture management for better and consistent growth of the tree that helps in various agroforestry practices is important. Similarly, the agronomical operation must be clear in the case of an agricultural crop. Processing, value addition, and marketing are significant constraints in agroforestry produce mainly wood and NWPs before the rural community. However, this perennial-based farming is boon to dryland farming due to the crops' hardy and resilient climate. Proper market linkage for agroforestry commodities through cooperatives, contract farming, buyback guarantee, green bonus policy, and other feasible means is a viable option.

Natural resource management through agroforestry is well documented in various studies in different ecologies across the globe. In dry regions, agroforestry-based interventions are directed for the amelioration of microclimate, improvement of the soil-water regime, and economic support to poor people. Peripheral bund planting with trees and shrubs for biofencing and fuel- fodder is the drier region is the primary source of the resource augmentation and conservation. The basic need of livelihood in the more parched region originated from the trees on-farm. Conventionally, traditional agroforestry practices are in vivid forms present in Indian arid and semi-arid regions. Khejiri (*Prosopis cineraia*) is one of the best examples of "*Kalp Virkash"* (wonder tree) of Rajasthan and the surrounding region. In the southern state of Tamilnadu, most pond ridges are planted by Babool (*Acacia nilotica)* trees.

Similarly, in Ladakh and Lahul Spiti's cold desert, seabuck thorn (*Hippophae rhamnoides*) is one such tree. There are trees with drought tolerance, and hardy to survive in severe water scarcity provide food, feed, and shelter in drought conditions, not the human being but also the livestock. The modified traditional home garden concept like "Wadi"is also based on the perennial promoting component in protecting and strengthening the poor farming community's economy with marginal land. Indigenous Traditional knowledge (ITK) in agroforestry linked with farming quotient (F.Q.) of the rural agricultural community for soil and water conservation in the principle of "Every field should have bund, and every bund should have trees." The Agroforestry quotient (AQ) of the farmers and local people from the ancient time is nature friendly to support the natural resource management with inclusion of trees in farming systems and restoration of degraded systems. There are several success stories from the Bundelkhand dry region by people sustaining their agriculture using agroforestry/ silvopasture/hortisilvipasture/silvimediculture. Resource utilization is not a problem, but their management on a long-term basis with the proper plan of action requires the government's political will. The Watershed management concept is well recognized and has tree/ perennial components in the watershed hub, followed by other components integration. All kinds of land restoration measures involve tree interventions at all levels and all types of degraded lands.

Livestock management is the main occupation in the arid and semi-arid region, mainly nurtured by nomadic herders like rabaris, maldharis, etc. These herders keep moving from one region to others, mainly depending on tree-based fodder during the lean period. Tree lopping and grass collection in silvipasture systems are rotated in situ or the fodder harvesting *ex-situ* application, *i.e.*, cut and carry or rotational grazing method. Agroforestry is a major resource for livestock due to diversified feedstuffs like leaf meal, grasses and fodder legumes, oil cakes of tree-borne oilseeds, etc. Grassland and rangeland management is attributed to agroforestry practices to rehabilitate degraded pastures through partial shade and rhizosphere association.

Thus, with a proper diagnosis and design approach, agroforestry has a vital role in natural resource management, resource mobilization, and utilization.

Agriculture is a fundamental source of national prosperity.

J. J. Mapes

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A fertile soil alone does not carry agriculture to perfection.

Elias Hasket Derby

Water management in dryland agriculture

Chander Kanta Kumawat[1*] and Gayatri Kumawat[2]

Dry land Agriculture refers to cultivation of crops entirely under natural rainfall without irrigation. Dry land agriculture is important for the economy as most of the coarse grain crops, pulses, oilseeds, and raw cotton are grown on these lands. Dry land areas receive rainfall between 500 and 1200 mm. The efficient use of water is crucial factor during crop growth periods which can greatly improve yield. Therefore, conservation of soil moisture by using mulching may be an efficient option to save water as well as rising production in dry land farming. Watershed management is a term used to describe the process of implementing land use practices and water management practices to protect and improve the quality of the water and other natural resources within a watershed by managing the use of those land and water resources in a comprehensive manner.

Dryland agriculture mean cultivation of crop under rainfed condition. Developing countries having less food security and more poverty crisis so major emphasis should be given on small scale water management in rainfed agriculture involving the redirection of water policy and large new investments. Rainfed agriculture dominant in world food production, but water investments in rainfed agriculture have been neglected over the past 50 years. Improvement in rainfed agriculture increases large social, economic, and environmental paybacks and help in poverty reduction and economic development. Rainfed farming covers most of the world's cropland (80%) and produces most of the world's cereal grains (more than 60%), generating livelihoods in rural areas and producing food for cities. Estimates suggest that about 25% of water management in irrigated area is required to attain the 2015 hunger reduction target of the Millennium Development Goal. The remaining 75% will have to come from water investments in rainfed agriculture. There is a close relationship among hunger, poverty, and water.The most hungry and poor people live in regions where water challenges are critical to food production. The world's hotspots for hunger and poverty are concentrated in the arid, semiarid, and dry subhumid regions of the world. There, water is a key challenge for food production due to the extreme variability of rainfall, grater evaporation rate than total precipitation, frequent drought and water scarcity, deep water table, bed quality of ground water, low crop productivity with less water use efficiency and floods. Rainfed agriculture covers some 40% of the world's land area and host roughly 40% of the world's population. In our country 33% are dryland 67% are rainfed area which, contribute about 44% national food production and after full exploitation it contribute about 75% of national food production. The water challenge in these rainfed areas is to enhance yields by improving water availability and the water uptake capacity of crops.

Dryland agriculture types:

(1) **Dry farming**: During cultivation of crop total annual rainfall is less than 750mm and prolong dry spell is the main region of crop failures. Ex: Arid region.

(2) **Dryland farming**: Total annual rainfall is 750 - 1150 mm during cultivation of crop. Ex: Semi-arid region.

(3) **Rainfed farming**: Cultivation of crop in area where annual rainfall is more than 1150 mm. Ex: Humid region.

Component of water management in dryland

1. **In-situ water management**: Increasing the infiltration of water or increased uptaking of rainwater through soil surface, rooting system

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and ground water. It include the practices which increased the water holding capacity and soil fertility and reduce the soil erosion.

Agronomic practices:

- ✓ **Tillage**: Summer ploughing leaves the soil highly absorbent of initial rains.
- ✓ **Dead Furrows**: Itaid in reducing the runoff velocity and conservation of water.
- ✓ **Organic Matter**: It improves the physical condition of the soil considerably soil -Air,soil temperature and soil – moisture.
- ✓ **Selection of drought resistant crops** : Common millet, barley, hickpeas, safflower (lower temperatures) sorghum, bullrush millet, phaseolus crops radiatus (gram mung bean), cassava, castor bean, sesame, groundnut (spanish variety), pigeon peas, sunflower.
- ✓ **Strip Cropping:** Help in more percolation of water into ground.
- ✓ **Line Sowing**: Line-sowing arrests runoff and conserves soil being eroded.
- ✓ **Mixed/Inter Cropping**: Main crop are grown with millets and legumes as insurance against of the variable monsoon.
- ✓ **Mulches:** Reduce evaporation, increase infiltration, and control growth of unwanted weeds and prevents the formation of hard crust after each rain.
- ✓ **Buffer Strips**: It helps in arresting soil erosion and conservation of rain water.

Mixed cropping (Castor +pigeon pea)

Live graded bund

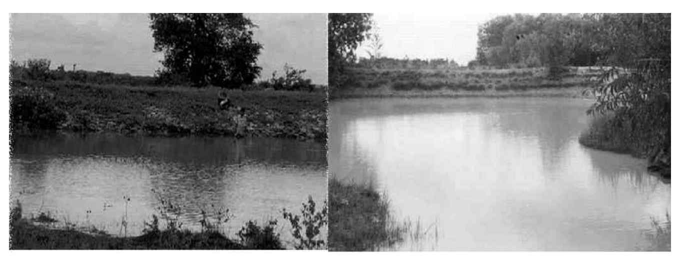
Conture trenches

B. Mechanical methods: Where the slope of the soil is more than permissible, mechanical measures such as bunding, terracing and trenching are recommended in addition to agronomic methods to retain water and minimize the loss of topsoil(Perry *et al.*, 2009).

Ex situ water management

1. **Farm pond**: Farm ponds are small tanks or reservoirs constructed for the purpose of storing water essentially from surface runoff and water used for irrigation, supply for the cattle and fish production etc.(Kumari & Singh 2016).
2. **Ground water recharge structure**

   Percolation tank: A groundwater recharge structures - Enhances yield of down-stream wells.



Percolation tank

- ➢ **Check dams/cement plugs/nala bunds**: It facilitate to recharge of stored water within short span of time.
- ➢ **Dugwell recharge**: Utilized as recharge structure after cleaning and desilting of the water through desilting chamber.

3. **Watershed management:** Integrate conservation and production technologies with watershed as a unit of management.

- ❖ Ensure maximum *in situ* rainwater conservation
- ❖ Harvest rainwater are recycled for agriculture production of high value crops, support establishment of tree crops and recharging grownd water.

Evolution of watershed concept in India

- **Topdown Approach :** Bio-physical emphasis (1980s)
- **Participatory Approach :** Bio-physical + Socio-economic (1990s)
- **Livelihoods Approach :** Integrated Watershed (2000)

Different governmental policies for water management:

- National Mission for Sustainable Agriculture (NMSA)
- Rainfed Area Development (RAD)
- Pradhan Mantri Krishi Sinchai Yojana (PMKSY) : Motto-Har Khet Ko Pani, Per Drop More Crop – for micro-irrigation.

Social Implications

- Participatory hydrological monitoring of water watershed area.
- *Panchayat* needs to be empowered legally to manage their resources, particularly groundwater in an equitable manner.
- Community-based water management and crop planning for sustainable use of groundwater.
- Tank rehabilitation to restore the livelihoods of various stakeholders dependent on them.

Dryland agriculture will be more contributed in the food production if more emphasis should given by govt. of India through implementing many policies for water management and providing more innovative knowledge to rural communities about different agronomic and mechanical practices of water management.

To make agriculture sustainable, the grower has got to be able to make a profit.

- Sam Farr

*****

Agriculture is the most healthful, most useful, and most noble employment of man

- George Washington

*****

When the Nobel Peace Prize Committee designated me the recipient of the 1970 award for my contribution to the 'green revolution,' they were in effect, I believe, selecting an individual to symbolize the vital role of agriculture and food production in a world that is hungry, both for bread and for peace.

- Norman Borlaug

*****

“When tillage begins, other arts follow. The farmers, therefore, are the founders of human civilization.”

- Daniel Webster

Conservation agriculture practice

K.P. Singh

It is associated with crop production that strives to achieve acceptable profits together with high and sustained production levels without degrading the environment and input natural resources. Interventions such as soil tillage are reduced to an absolute minimum and the use of external inputs such as agrochemicals and nutrients of mineral or organic origin are applied at an optimum level and in a way and quantity that does not interfere with the biological process.

Conservation Agriculture (CA) is a system of integrated management of soil, water and biological resources combined with external inputs with a view to conserve the natural resources. Conservation tillage as compared to conventional practices, showed better performance in terms of increased benefit: cost ratio (2.0-2.5) and water operational energy (5-26%). Zero tillage improves the soil drainage avoiding the sponge effect created by normal cultivation. The effect of direct seeding/ planting has been found to be advantageous in terms of improved trafficability, decreased soil compaction in long run and reduced soil erosion due to wind and water. It also leads to decreased water evaporation and increased availability water in to the soil and decreased lodging.

Principles of conservation agriculture

The principles of the conservation agriculture are discussed below.

Disturb the soil as little as possible

- Conventionally, ploughing or hoeing destroy the natural soil structure, and creates a hard layer that roots cannot push through.
- Conservation agriculture breaks through the hard layer, letting water to seep into the soil and allowing roots to grow down.

Keep the soil covered as much as possible

- Ploughing exposes the soil to the rain and sun. The soil is washed away easily by heavy rain, causing erosion.
- Conservation agriculture protects the soil surface and prevents erosion.

Mix and rotational crops

- Planting the same crop season after season allows pests, diseases and weeds to multiply. That means lower crop yields and a monotonous diet.

Conservation agriculture: theory and practice

- Mechanization Technologies for Sustainable and Profitable Agriculture in African-Asian Region
- Conservation agriculture mixes and rotates crops to break the life-cycle of pests, diseases and weeds. That results in higher yield and a more varied diet.

Objectives of conservation agriculture

The objectives are to improve agricultural production by adopting economically, ecologically and socially sustainable methods with aims to conserve, improve and make more efficient use of natural resources. It contributes to environmental conservation as well as to enhanced and sustained agricultural production for farmers.

Impacts of conservation technologies

Conservation agriculture (resource conserving technologies) plays an important breakthrough for sustaining productivity, natural resource conservation with economic growth of farmers. It is estimated that for each litre of diesel fuel consumed, 2.6 kg of CO_2 is released to the atmosphere. Assuming that

150 litres of fuel is used per hectare per annum for tractor uses and irrigation purposes in conventional system, would amount to nearly 400 kg CO_2 being emitted per annum per hectare. Rice-wheat is the dominant system in India wherein conventional method of land preparation/sowing, not only disturbs

ICAR-CIAE, Bhopal, MP

the soil environment but also leads to atmospheric pollution. Resource conservation technologies have been proved to be the important steps in the conservation agriculture and economic growth. Aerobic rice culture has been demonstrated well in Indo-Gangetic Plain, which has substantial potential for minimizing the cost of production, soil health hazards and the negative impacts on the succeeding crops.

Further, significant reduction in methane (CH_4) emission from rice-paddy cultivation was also observed due to adoption of resource conservation technologies (aerobic rice), particularly in rice-wheat production system. The major components of CA includes minimal soil disturbance, maintaining soil cover and crop diversification. The evaluation of various “Conservation Agriculture” technologies for their farm level impact in the country as detailed below has shown tremendous potential for resource conservation and sustainable farming.

Incidence of Weeds: Most studies tend to indicate reduced incidence of *Phalaris minor*, a major weed in wheat, when zero-tillage is adopted resulting in reduced use of weedicides.

Water and nutrients: Limited experimental results and farmers experience indicate that considerable saving in water (up to 20-30%) and nutrients are achieved with zero-till planting and particularly in laser levelled and bed planted crop.

Increased yields: In properly managed zero-till planted wheat yields were invariably higher by 4 – 6% compared to traditionally prepared fields for comparable planting date.

Cost of production: This is a key factor contributing to rapid adoption of zero - till technology. Most studies show that Rs.1500 reduces the cost of wheat production to Rs. 2,000 per hectare. Cost reduction is attributed to savings on account of diesel, labour and input costs, particularly weedicides.

Environmental benefits: The CA involving zero-till and surface managed crop residue systems are an excellent opportunity to eliminate burning of crop residues which contribute to a large amount of greenhouse gases like CO_2, CO, NO_2, SO_2 and particulate matter. Burning of crop residues also contributes to considerable loss of plant nutrients, which could be recycled when properly managed. Large-scale burning of crop residues is also a serious health hazard.

Crop diversification opportunities: Adopting CA system (includes planting on raised beds) offers opportunities for crop diversification. Cropping sequences/rotations and agroforestry systems when adopted in appropriate spatial and temporal patterns can further enhance natural ecological processes, which contribute to system resilience and reduced vulnerability to yield reducing disease/pest problems.

Resource improvement: No tillage when combined with surface managed crop residues sets in the processes whereby slow decomposition of residues results in soil structural improvement and increased recycling and availability of plant nutrients. Surface residues acting as mulch, moderate soil temperatures, reduce evaporation, improve biological activity and provide more favourable environment for root growth, the benefits which are traditionally sought from tillage operations.

Conservation agriculture for sustainability

Conservation agriculture provides a truly sustainable production system, not only conserving but also enhancing the natural resources and increasing the variety of soil biota, fauna and flora (including wild life) in agricultural production systems without sacrificing yields on high production levels. As CA depends on biological processes to work, it enhances the biodiversity in an agricultural production system on a micro as well as macro level. The CA in the context of sustainable agricultural mechanization is more than just a mechanical technique, such as no-till and direct seeding. It represents a fundamental change in the soil system management and in the cropping system design and management, which in turn lead to consequential changes in the required field operations and the related mechanization solutions. When a tillage-based production system is to be transformed into a CA-based system, it involves a shift in the prevailing on-farm mix of mechanical technologies, some of which will remain but with only marginal use in future and there will be development of completely new set of mechanical technologies, changes in farm power requirements and in land use suitability for sustainable intensification.

Mechanization strategy in conservation agriculture

Agricultural machinery or tools, which support conservation agriculture generally refer to the cultivation systems with minimum or zero tillage and *in-situ* management of crop residues. Minimum tillage is aimed at reducing tillage to the minimum necessary that would facilitate favourable seedbed condition for satisfactory establishment of crop. Zero tillage is, however, an extreme form of minimum tillage. With the development of direct drilling machines almost all research work was attempted to define the responses of direct-drilled seeds in relation to soil microenvironments. Different designs of direct drilling machines, *viz.* zero till drill, no till plant drill, strip till drill, roto till drill and rotary slit no till drill have been developed with controlled traffic measures for energy efficient and cost-effective seeding of crops without tillage. Laser guided land leveller and roto tiller helped to retain in-situ soil moisture longer thereby reducing the irrigation demand. Under rain fed conditions, a shift towards higher productivity, decentralized micro-irrigation system can help in saving water.

Selection of most appropriate developed equipment for specific situation is essential in respect of field requirements (alleviate soil compaction, soil loosening only in crop rows or surface soil loosening with or without straw mulching); soil working condition (high moisture plastic, moist-friable or dryfriable soils); type of equipment (discs or inverted). In India, significant efforts are underway to develop and popularize the agricultural machinery and tools through the combined efforts of several state and national institutions, particularly rice-wheat consortium for Indo-Gangetic Plains.

Conservation tillage

Tillage is an important and primary tool for conservation of land. As per definition, its primary purpose is to provide a favourable soil environment for plant growth, which is indirectly related to soil conservation. The effect of tillage on soil erosion is function of its several effects on soil such as aggregation surface sealing infiltration and resistant to erosion destruction of soil structure either by excessive tillage or tillage operations at improper soil moisture condition tends to increase the soil erodibility, causing significant soil loss. Conservation tillage, which includes no-till, and reduced tillage, is defined as any tillage or planting system that maintains at least 30% of the soil surface covered by residue after planting. Ploughing and soil turnover, from conventional tillage, are major reasons for CO2 emissions from soils. Lower, but still substantial mitigation potential is provided by: rice management by following SRI (system of rice intensification)/ Madagascar method or direct sowing of rice and livestock management (including improved feeding practices, dietary additives, breeding and other structural changes, and improved manure management (improved storage, treatment and handling). To achieve the best result for soil conservation, following points should be considered for tillage operations.

- Till no more than necessary
- Till only when soil moisture is in the favorable limit and
- Vary the depth of tillage to overcome the compaction.

Zero tillage (no-till or direct seeding): A system where the soil is not disturbed between harvesting one crop and planting the next. It is a crop production where the soil is not traditionally tilled or cultivated although sticks or other planting equipments used to make the openings for seeds. No−till requires surface application of pre-emergence or post-emergence herbicides for weed control. One or two properly timed applications may be necessary. No−till planting is well suited to many soils. Residue, when uniformly spread, increases water infiltration and reduces soil moisture evaporation. Using no−till in poorly drained soils covered with large amounts of residue, delays soil warming which delays germination and emergence. When colder, wetter soils are a concern with early planting dates, use no−till planter attachments designed to move residue but not soil away from the row. No−till planting is well suited to many soils.

Residue, when uniformly spread, increases water infiltration and reduces soil moisture evaporation.

No till drills: Drills used for direct sowing of seed without tillage are described below.

Zero till (no till) seed cum fertilizer drill: It is 26.11 kW or above tractor-operated sowing equipment and is used for sowing wheat, maize and other forage crops on zero- tilled or semi-tilled soils. It helps to sow the seed at a required appropriate depth thereby economize the use of inputs save time, labour, fuel and irrigation expenses as compared to traditional methods of sowing.

Happy seeder: The happy seeder technology offers a solution to the problem of direct drilling into Mechanization Technologies for Sustainable and Profitable Agriculture in heavy stubbles, enabling the stubble to be retained on the surface as mulch. The equipment is the combination of straw handling unit and sowing unit. It is used for sowing operation in combine harvested field in a single pass while retaining the crop residue as surface mulch. The unit is compact, light weight and tractor-mounted capable of managing rice stubbles and loose straw in a strip just in front of each furrow opener. The modification included development of straw handling rotor to cut the standing stubbles to width of 75 mm, and thereby leaving 125 mm strip of standing stubbles between two furrows. The modified design has reduced the total straw load by 30%. It is operated by a 33.57 kW tractor and covers 2.5-3.0 ha/day. A strip-till rotor has also been placed in one of the designs between straw handling unit and furrow opener to provide better soil pulverization and to enhance soil-seed contact. The unit price is `60,000 and the break-even acreage is 30 ha. The operating cost is in the range of `1,500-1,750/ha. John Blackwell of Punjab Agricultural University, Ludhiana, has developed the original happy seeder for direct drilling of wheat in rice residues. Happy seeder was improved in design and improved version is named combo happy seeder. The combo happy seeder was used to sow wheat in to rice residues (of up to 9 t/ha) in numerous sites of Punjab and more recently other parts of India and Pakistan with very encouraging results.

Minimum tillage: It is till plant system. The tilling of soil and seeding/planting are performed simultaneously. It is a practice of minimizing soil disturbance and allowing crop residue or stubble to remain on the ground instead of being thrown away or incorporated into the soil. This minimum tillage practices may progress from reducing the number of tillage passes to stopping tillage completely (zero tillage). The cover of crop residue helps prevent soil erosion by water and air, thus conserving valuable topsoil. Another important environmental effect is the reduction in use of fossil fuels on the farm.

Roto till drill: It is 26.11 kW or above tractor operated equipment and is used for sowing seeds into the soil directly opened with the help of rotavator attached with the machine, in a single operation in the stubble fields. The machine performs the tillage operation and directly place seed and fertilizer in the soil opening in the stubble fields of paddy, maize and sugarcane. Cost reduction by time and energy saving and optimization of environmental health by reducing soil compaction are the main highlighted features of this machine field and thus increases the yield.

Slit till drill: It is 26.11 kW or above tractor-operated equipment and is used for sowing seeds into the slits opened with the help of rotary slit disc, attached in front of the furrow openers of machine, in a single operation in the stubble fields. The machines prepare a 20 mm slit in the soil and places seed and fertilizer in the prepared slits in the stubble fields of soybean, maize and paddy. The machine works very well under no till condition and very small vertical slit of 20 mm width and 40 mm depth is opened in straw covered field for placing seed and fertilizer in slit. It reduces the loss moisture and draft force as compared to strip and roto till drill.

FIRB farming system and equipment

Furrow irrigation raised bed (FIRB) farming system for wheat was originally developed in Maxico's Yaqui Valley, where irrigation water is delivered through the field by furrows between the beds, which range in width from 0.7 –1 m from furrow to furrow; depending on the distance between the tractors tires single row is planted on top of the each bed for row crops like maize soybean, cotton, sorghum, Mechanization Technologies for Sustainable and Profitable

Agriculture in African-Asian Region 43 sunflower and dry bean; 1–2 rows per bed are planted for crop like chick pea and canola; but 2–4 defined rows , spaced 15–30 mm depending on bed width are used for wheat. Bed shapers are used behind the tractors to form furrow-beds to sow row crops. Bed planting decreases the soil surface exposed to flooding by 40%, which eliminated surface soil crusting on the top of the bed where the wheat was planted. In addition, soil porosity with bed planting is larger than for flat planting, resulting in lower soil bulk density for bed planting, especially for 0–100 mm soil profile. Over time with additional irrigations, the porosity of flat planting is reduced and bulk density increases as compared to bed planting.

Package of equipment for bed forming

Tractor having 26.11 kW or more or tractor having narrow width traction wheel tyre size (8.3 × 28) with front and rear power take off could be used with appropriate implements matching with tractor for bed cultivation of agricultural crops.

Strip-tillage: In this system of tillage, a narrow strip (100-200 mm) of land along with the row is tilled and areas between the rows are left undisturbed. In this system, planting is performed with a single tiller and planter in a single operation for highly mechanized tillage system. It combines the soil drying and warming benefits of conventional tillage with the soil-protecting advantages of no-till by disturbing only the portion of the soil that is to contain the seed row.

Strip till drill: It is 26.11 kW or above tractor-operated equipment and is used for sowing seeds into the strips prepared with the help of rotavator, attached with the machine, in a single operation in the stubble fields. The machines prepare a 50 mm strip and places seed and fertilizer in the prepared strips in the stubble fields of paddy, maize and sugarcane. Cost reduction by time and energy saving and optimization of environmental health by reducing soil compaction are main features of this machine which is a power roto/ drill combination.

Combination tillage: It is combination of two or more than two tillage operations in one pass such as disc harrowing and clod crushing by clod crusher and sweep cultivation and pulverizing the soil with roller etc. Multiple passes of primary and secondary tillage comes at a high cost in fuel, labour and machinery. This practice often does not leave enough residue cover (30% or more to be rated as conservation tillage) for protection from soil erosion, especially following soybean. This tillage is could save farmers labour, fuel and machinery costs.

Controlled-Traffic Farming

Controlled traffic farming is quite simply controlling traffic in the farming system with the result of improving efficiency and farm output. A system that controls traffic separates wheel beds and root beds. In conventional farming we work the soil to make it suitable for cropping, and then drive very heavy machinery over it in the act of cropping. About 85% of the field becomes compacted from heavy machinery. Controlled traffic farming is most suited to continuous cropping systems, which exclude livestock from the cropping area. There are also a lot of farmers having a lot of success with raised beds and controlled traffic in horticultural systems. Soil strength is indicator how easily root can penetrate soil. Cone index is measure of soil strength and is measured using a penetrometer. The magnitude of mechanical impedance to root to penetration, which decreases plant growth, is also unknown.

Bed cultivation for soil compaction

Controlled traffic minimum tillage systems might be seen as a second phase of conservation agriculture, overcoming the direct costs, subsurface degradation and system impacts of wheel ruts from random wheel traffic. Extensive field trials in the country has shown that planting of wheat, pulses, and vegetables on beds results in increase yield, fertilizer-use efficiency, reduce herbicide dependence, better weed management and mobility in the field, beside saving of seed, fertilizer, irrigation water and soil compaction. An improvement upon zero-tillage can come if crops are grown on the ridges of a ridgeand-furrow planting configuration. This is, however, profitable only if farmers shift to a permanent bed system, *i.e.* zero-tilled crops on raised beds. After wheat harvesting, rice can be either direct-sown on beds or transplanted onto wet beds. Controlled traffic in furrows can prevent compaction in the beds. This can be a significant benefit over time, especially in zero-tilled fields. It also results in more compaction at the bottom of the furrow, which restricts vertical water flow (seepage) and helps wet the adjacent beds through better horizontal flow. It offers farmers an alternative to herbicide use for weed control since most weeds can be controlled by mechanical cultivation by driving down the furrows. Herbicide application is also much easier with beds, since nozzles can apply the herbicide uniformly over the bed and by using the bed as a guide for the applicator. Similarly, these systems offer an opportunity to band basal and topdress fertilizer applications, instead of broadcasting them, which improves efficiency. The beds permit more diversity in croppingsystems during the summer season, as better drainage can be maintained for crops on beds during the monsoon period.

Mulching/green manuring/crop residue incorporation

Mulching is defined as the application of any plant residues or other materials to cover the top soil surface for conserving the soil moisture, reducing the runoff and thereby to control soil erosion, checking weed growth, improving the soil temperature and modifying the micro-environment of soil to meet the needs of seeds for their good germination and better growth of seedlings. It is known to attribute the suppression of the weed growth conservation of moisture by checking evaporation and runoff to protect the soil against erosion (mainly from wind) to increase infiltration of water to fluctuate the soil temperature to enhance mineral nutrient availability to enhance nitrification to add nutrients and organic matters derived from decomposing of residues or other materials used as mulch to preserve or improve the soil structure. Mulching also improves the soil aeration creates better biological activates and thus to make a consequent beneficial effect on the soil fertility. Green manuring is the practice of applying as manure large quantities of green material such as leaves and twigs of plants or crops growth for this purpose. Growing of a crop or applying of leaves and twigs of plant incorporating it with the soil is called 'green manuring'. Green manure, also called a cover crop, is a great way to add nutrients to the soil. Green manure means planting a crop that is meant to be incorporated into the soil to increase its fertility.

which are as follows:

- **Green manuring *in situ*:** Growing a crop and incorporating (ploughing) it in the same field with the soil is called situ method of manuring.
- **Green leaf manuring:** when green leafy material is collected from other places and ploughed in the field it is known as green leaf manuring.

Crop residue incorporation

Crop residue incorporation is done to improve soil carbon and nutrients in soil. The use of microbial sprays that can speed decomposition of residue is also an option. The incorporation of cereal crop residues immediately before sowing/transplanting into wheat or rice significantly lowers crop yield because of immobilization of inorganic N and its adverse effect due to N deficiency. However, wheat yields are lower during the first one to three years of rice straw incorporation, 30 days prior to wheat planting, but in later years, straw incorporation does not affect wheat yields adversely. No-tillage with residue retention and with 50% of the recommended NPK application, would effectively have the total carbon equivalent emissions to 14 tonnes CO2/ ha/ year compared to high input conventionally tilled cropping system with residue burning and organic amendments due to improved nutrient use and environmental efficiency. The raised-bed planting system offers avenues for incorporating residue by attaching shovel-type openers in front of the seed-cum-fertilizer openers and bed-shaper. The shovel shapes the old beds and covers the crop residues with soil taken from the furrows. To facilitate the drilling operation in combine harvested fields, the first step should be to attach flappers or swappers to combines for shredding of rice residue and to spread them more uniformly. Leaving mulch on the surface improves soil moisture and thermal regimes. No-tillage with residue retention and with 50% of the recommended NPK application, would effectively have the total carbon equivalent emissions to 14 tonnes CO2/ ha/ year compared to high input conventionally tilled cropping system with residue burning and organic amendments due to improved nutrient use and environmental efficiency. Zero-tillage also reduces

CO_2 emissions by slowing oxidation of the carbon stock due to reduced soil disturbance. The raised-bed planting system offers avenues for incorporating residue by attaching shovel-type openers in front of the seed-cum-fertilizer openers and bed-shaper. The shovel shapes the old beds and covers the crop residues with soil taken from the furrows. The following should be targeted for the future:

- *In situ* incorporation being the best option may be further investigated for fast decomposition of residue.
- Technological improvements in the implements used, so that the option of planting into residue, drilling operation, *in situ* incorporation, etc. can be made feasible.
- Modifications of combine harvesters where the residue also is separately collected and removed from the field.

System for Rice Intensification

System of rice intensification (SRI) represents a strategy for improving crop growth, yield and factor productivities that is based on well-known agronomic and plant physiological understanding in particular. It capitalized on the growth and functioning of profuse, healthy roots that are proportional to the above ground capacity to trap and utilized solar radiation most efficiently and the abundance, activity and diversity to beneficial soil biota, which help nourish plant and, enhance their resistance to pathogens and other stresses.

Features of SRI system

Reducing water application: Under hypoxic soil conditions rice plant roots do not developed fully and are abnormal. The roots that do grow degenerate prematurely becoming functionally less and less effective, taking less soil nutrient and water. Also under anaerobic soil condition, the soil biota are less numerous and less diverse. The aerobic bacteria able to fix N, solublize P and provide other benefits to plant cannot functions under such conditions: nor can mychorizal fungi provide their various services. An additional important benefit of aerobic soil condition is the development of larger root system giving the plant larger exploitable root zone in the soil, which under anaerobic condition are further restricted by

the hard pan needed to hold water for maintaining flooding. The profuse root systems that develop SRI management improve the plant access to nutrient soil moisture and thereby also enhance their resilience against biotic and abiotic stresses

Reducing plant population: The SRI proposed optimization of scarcity to achieve balance between performance of individual plants and crop area. In conventional practice, seeds up to 120 kg/ha are recommended to achieve to high density of panicle-bearing tillers. With SRI, on the other hand, with young seedling no crowding and aerobic soil conditions, an even higher panicle-bearing tillers density can be produced with seed rate as low as kg/ha. The SRI practice as against as conventional practice minimizes competition below and above ground, thereby encouraging greater root and canopy growth and distribution. Plant canopies have more uniform access to solar radiation while soil nutrients can be captured from a larger soil root zone. At the same time the photosynthetic process is prolonged and there is greater translocation to panicle of carbohydrates and nutrients stored in the rest of the plants.

Transplanting younger, smaller seedling: Young seedling, although they look more vulnerable and unpromising then older, larger once have a far greater vigour and potential for canopy development and consequently they mature into more productive plants.

Nutrient management*:* The SRI is agro-ecological and necessarily not necessarily organic. Most of the best results with SRI methods have been achieved with fully organic nutrient management but usually after some years of organic soil enhancement, which improve both the structure, and functioning of soil systems. A significant positive interaction is between the soil moisture regime and the effect of organic fertilizers is likely, as the mineralization soil oxygen levels affect process.

System of wheat intensification

The system of wheat intensification (SWI), is an adaptation of techniques used in the system of rice intensification (SRI). **It** is a methodology for improving sustainable productivity of wheat- based systems through: i) increasing understanding of the crop and local environment and how they interact; ii) improving management of cropping systems and thus, sustainable yield; and iii) increasing diversification. It proposes on-farm trials and training for facilitators and farmers working as equal partners. It is a dynamic process in which local reference values (checkmarks) are obtained through on-farm research and are used to detect potential areas for improvement. The trials are not fixed recipes with fixed ingredients but conceptual recipes that encourage understanding and modifications in order to address local needs and circumstances.

Equipment for Residue Management

Crop residue management is essential for successful direct seeding. Maintaining crop residue, rather than baling, burning or tilling, offers many benefits. These include increased snow catch and water infiltration, reduced moisture evaporation, increased soil organic matter, improved soil structure and plant nutrient cycling, virtually no chance for wind erosion and much reduced potential for water erosion, and the reduction of some weed species. Crop residue must be spread evenly to avoid or reduce such problems as: equipment plugging; poor seed germination; disease, weed and insect infestations; nitrogen tie-up in the chaff or straw rows; and cold soil. For managing the crop residue in the field following equipment are used.

Stubble shaver

It is 26.11 kW or above tractor-operated crop stubble chopping and spreading machine. It is used to chaff and spread the crop stubble of wheat, maize, paddy and other crops by the rotating cutter operated by PTO of the tractor. The machine is very use full to prepared the field for direct drilling of crops under heavy stubble condition. The chaffed straw can be incorporated in soil by use of mould board plough or rotavator or both the implements effectively.

Rotary slasher

Rotary slasher helps in performing the most versatile method of grass cutting, *i.e.* slashing. It is powerful enough to cope with tall weeds and small bushes, providing better results by keeping scalping Mechanization Technologies for Sustainable and Profitable Agriculture in African-Asian Region 48 to minimum. The machine has a light but strong construction to suit the 35 hp or above tractors. It is one of the best machines for cutting unwanted wild grass and very cost-effective for medium size grass cutting. The tried and tested cutting gear ensures a clean cut in all conditions. Slashed and spread grasses can be incorporated into the soil by the operation of rotavators or MB Plough.

Carbon Sequestration, Carbon Trading, Carbon Credits

The largest contribution to mitigate climate change with conservation agriculture could be obtained from carbon sequestration and the storage of atmospheric carbon in soil. On an average, 0.1-0.5 tonnes/ ha/year of organic carbon can be captured under humid temperate conditions. For this farm equipment like stubble shavers, rotary slasher, rotavators and no or minimum tillage seeder/planter, happy combo seeder are required for incorporation of crop residues in to the soil and direct seeding/planting without tillage under crop residue condition. It is estimated that global conversion of all croplands to conservation tillage (CT) could sequester 5 billion tons of carbon annually. Sink of carbon from the atmosphere to either plant in to the soil or from atmosphere to the soil is called carbon sequestration. Soil organic

carbon is fundamental to the development of soil quality and sustainable food production system. The organic carbon is high sensitive to changes in land use and management practices such as increased tillage, cropping systems, fertilization etc. leading to soil organic carbon decline. Soil contains both (weathered rock particles and minerals) and inorganic (plants, animals, insects and microbes) components. Soil carbon content can be either expressed as either a concentration (%) or a stock (tonnes/ha). Bulk density and C content increases with soil depth. For every tonne of carbon lost from soil adds 3.67 tonne of CO2 gas to the atmosphere.

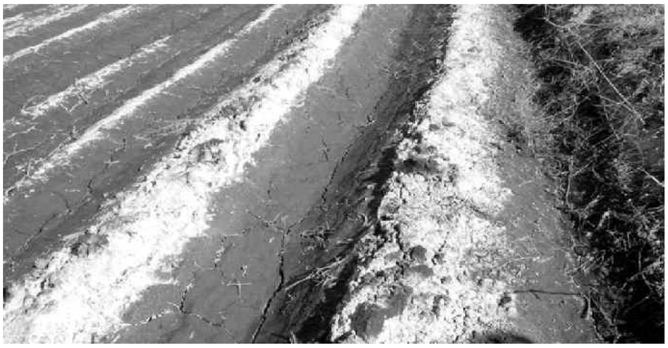
Reclamation of salt-affected soils with suitable technologies

Mukesh Kumar[1], R.K. Singh[2], Ramadhar Singh[2] and Ajita Gupta[1]

The amount of crop yield reduction depends on the factors such as crop growth, salt content of the soil, climatic conditions, etc. In extreme cases, where the concentration of salts in the root zone is very high, crop growth may be entirely prevented. To improve crop growth in such soils the excess salts must be removed from the root zone. The term reclamation of saline soils refers to the methods used to remove soluble salts from the root zone. Removing the salts that have accumulated on the soil surface by mechanical means has had only a limited success although many farmers have resorted to this procedure. The actual choice will however depend on the availability of water and other considerations.

By 2050, the world's population is projected to increase by 34% reaching 9.1 billion with major share in the developing countries. The total food requirement will increase by more than 55%, equal to 800 million tonnes of additional food. Besides, declining water table depths and deterioration of water quality are major concern inmany parts of the world today. The soil degradation by increased salinity is one of the major reasons for decreased crop yield in the regions. The problems of soil salinity are most widespread in the arid and semi-arid regions of the world. Moreover, salt-affected soils are also extensively found in humid and sub-humid climates, particularly in the coastal regions. The sea water intrusion takes place through estuaries and rivers and also through groundwater that causes large-scale salinization. Soil salinity is also a serious problem in areas where groundwater of high salt content is used for irrigation. The most serious salinity problems are being faced in the irrigated arid and semi-arid regions of the world. The area under salt-affected soils is around 6.73 Mha which is equivalent to 2.1% of total geographical area of the country. Salt-affected irrigated land in the world and in India is about 20% and 17% of total irrigated land, respectively. Moreover, 0.2-0.4% of the total arable land every year is going out of cultivation because of salinity and water logging problem.

Salt-affected soils contain excessive amount of either soluble salts or exchangeable sodium or both affecting crop yields and ultimately crop production. These soils are classified into saline, sodic and saline-sodic depending upon the physiochemical properties and the nature of the salts. The process by which saline soil is generally formed is called salinization. The various reasons which facilitate the formation of salt in the soils are- when rainfall is not sufficient for adequate leaching of salts and the phenomenon is common in arid reasons. The common salt ions which form the salinity are Ca^{2+}, Mg^{2+}, Na^{+}, Cl^{-}, SO_4^{2-}, HCO_3^{-}, CO_3^{2-}. The chemical characteristics are such that Electrical Conductivity (EC) of the saturation soil extract is more than 4 dSm^{-1} and pH of the soil remains less than 8.5. ESP is less than 15 in case of saline soil. The soil structure of saline soil is generally good and infiltration rate is found high with good soil aeration. The salts ions increase the osmotic potential of soil solution which ultimately reduces the available soil water. The plants have to use more energy to draw available water from the soil for their daily evapotranspiration. It affects the plant uptake of nutrients and the microbiological activities in the soil. Plant growth is adversely affected in sodic soils due to excess exchangeable sodium in sodic soils which has a great influence on the physical soil properties. With the increased proportion of exchangeable sodium, the soil tends to become more dispersed which results in the breakdown of soil aggregates and ultimately lowers the permeability of the soil to air and water. The accumulation of certain elements in plants at toxic levels may result in plant injury or reduced growth and even death with specific ion effects. Elements more commonly toxic in sodic soils include sodium, molybdenum and boron.



Salt affected soil with salt crusts on top of ridges (Source: www.fao.org)

Reclamation of salt-affected soils

The various mitigation measures for reclamation of salt-affected soils are given below-

Physical measures

Leaching technique is one of the physical mitigation measures used for saline soils. In this technique, the salt ions after dissolving in water move down from upper surface to the lower level of soil column. In this process, the salt ions which are the actual saline elements transferred to lower parts of the root zone of crops causing less harm than the earlier. Leaching requires huge amount of water for soil reclamation. Therefore, in this process, fresh non-saline water is applied to the field by irrigation. This fresh water washes out the excess salts from root zone and carries away beyond the root zone of the crop. Generally, it is found that salt-affected soils form heap of salt on the surface which may be removed by scrapping out from the field. But, there are limitations with this method that may not be feasible for large areas. The other physical measures may be taken as facilitating proper drainage of additional water which is not desirable for the plants. Moreover, the drainage system should be improved so that upward movement of ground water up to soil surface is ceased and water applied to the crop field can move down through the soil profile. This keeps the soils draining out salts ions and reduces the salinity. So, proper drains may be constructed at the field for removal of excess water.

Chemical measures

In case of sodic soils, a fresh source of soluble calcium to replace the sodium adsorbed by the soil is added. The excess exchangeable sodium needs to be replaced by a divalent cation, preferably calcium. The sources of soluble calcium must be made available in sufficient quantity for cation exchange process to take place. Moreover, the leaching is carried out until the replaced sodium is removed.

The most common parameter used in soil salinity is the electrical conductivity of the extract (EC) of a saturated soil paste in units of deci-Siemens per metre (dS/m).

- EC 0–2dS/m; non-saline soil
- EC 2–4dS/m; slightly saline, yield of sensitive crops reduced
- EC 4–8 dS/m; moderately saline, yield reduction of many crops
- EC 8–16 dS/m; saline, normal yield for salt tolerant crops only
- EC > 16 dS/m; reasonable crop yields only for very tolerant crops

The gypsum (calcium sulfate) is most commonly used chemical treatment to supply calcium for the reclamation of sodic soils. Since, the benefits are expected from the reclamation of salt-affected soils that would not be obtained unless adequate plant nutrients are supplied as fertilizer. Therefore, the proper types and balanced amounts of mineral fertilizers should be used in these soils. Moreover, some of the studies indicate that crop yield may also be increased with the foliar application of potassium sulphate during heading stage of the crop. The grain yield of wheat cultivars under saline irrigation regimes increases with the specific dose of potassium sulphate (K_2SO_4) as foliar spray in the ratio K^+:Na^+::1:10 during the heading stage of the wheat crop. Foliar application of potassium sulphate has been found to mitigate the adverse effect of the salinity on the wheat crop.

Other measures

Other measures include improved agronomic, irrigation water and nutrient practices; alternate land uses; and use of salt-tolerant varieties. The ICAR-Central Soil Salinity Research Institute (CSSRI), Karnal (India) is having an all India mandate to give an impetus to the reclamation of salt affected soils and use of saline water in the country. This Institute has developed a number of salt-tolerant crop varieties and is in great demand. The salt-tolerant wheat varieties are KRL 19, KRL 210 and KRL 213 developed by ICAR-CSSRI, Karnal. A few salt tolerant rice varieties developed by CSSRI, Karnal are CSR 2, CSR 27, CSR 30 and CSR 36. The main aim of these salt-tolerant crop varieties is to mitigate the adverse effect of salt and to sustain the crop yield in salty environment. Alternate land uses of salt affected soils are to grow halophytes (a salt-tolerant plant such as Cressa, Spartina, Limonium *etc.*), medicinal (such as *Aloe vera, neem, etc.*), aromatic (*i.e.* Gumweed) and spices.

Plantation of high water consuming tree species for withdrawal of ground water is termed as bio-drainage. It is a preventive technique to avoid the development of salinity and water logging problem in canal commands. *Eucalyptus, Populus, Laucaena* and *Bambusa* are some of the high water consuming tress that may be used in waterlogged area. Scientific study shows that Eucalyptus tree removes about 53% of the highly saline water (12 dS/m) vis-à-vis control conditions and thus arrested salinity development in the root zone. Integrated drainage system comprising of subsurface drains, tree belts (bio-drainage), evaporation cum fish ponds and agro-forestry based systems seem promising for amelioration of waterlogged saline soils in areas without adequate outlets in the states of Haryana, Punjab and Rajasthan. Growing of sea weeds which fetches higher price in national and international markets is also some alternative use of such lands. The improved cropping system for sustained livelihood of the coastal agricultural communities is also essential.

Management of saline soil is important for sustainable crop production to feed the burgeoning population. The uses of new technologies available for reclamation of salt-affected land are helpful in crop cultivation in saline condition. The alternative use of salt-affected land plays important role in such areas. With the new cost-effective reclamation technologies available for salt affected soils farmers can plan and choose suitable management alternatives. The gypsum (calcium sulfate) is a common method to supply calcium for the reclamation of sodic soils. Bio-drainage also plays major role in salinity and water logged areas. The improved agronomic, irrigation water and nutrient practices with alternate land uses and use of salt-tolerant varieties have the great potential for productive use of salt-affected soils.

Agriculture is at the core of the state.

- Dave Cook

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Agriculture is the process of turning eco-systems into people.

-Toby Hemenway

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A Sustainable Agriculture does not deplete soils or people.

- Wendell Berry

Pant Arhar-6 : A new high yielding pigeonpea variety for Bundelkhand region

Amit Kumar Gaur[*], Harshdeep, Harikant Yadav, Charupriya Chauhan and S.K. Verma

Agriculture is the main source of livelihood in Bundelkhand region and pulses are the most important crops cultivated in this region. During the last two decades this region has faced severe droughts due to which production of pulses decreases. Pigeonpea is the major *kharif* pulse of Bundelkhand region. Pigeonpea is an ideal pulse for this region as it is drought tolerant, fetches high price in the market and its production requires minimal irrigation among all pulses. Recently, a new improved variety of Pigeonpea *i.e.* Pant Arhar-6 (PA 421) was released by G.B. Pant University of Agriculture and Technology. This variety will be highly beneficial for the farmers of Bundelkhand region as it is high yielding (17-20 q/ha), early maturing (140-145 days), good protein content (22%) and has moderate resistance against *Helicoverpa*, *Maruca*, *Apion clavipes* and bruchids insects.

Bundelkhand region is quite large, spread in about 69,000 sq. km. area covering seven districts of Uttar Pradesh and six districts of Madhya Pradesh. It is a semi-arid climatic region receiving an average rainfall of about 800 mm. Water availability is very scare even for human consumption. The livelihood of farmers in Bundelkhand region is mainly dependent on agriculture. Since the pulse crops are suited for cultivation in such areas, a number of pulse crops particularly deep rooted crops like pigeonpea (arhar) is the ideal choice for cultivation in *kharif* season. Being a deep rooted crop, pigeonpea plant can extract the moisture from the deeper strata of the soil. Almost all plant parts of pigeonpea are usable. Grains in split form are used as arhar dal and are consumed almost on every alternate day in each household of this region. After harvesting the grains, the remainder plant parts particularly branches and stem which is woody, is used as fuel. Pigeonpea plant produces lot of biomass particularly leaves, which after fall increases the soil fertility.

Early maturing pigeonpea varieties sown in the second forthnight of june with the onset of monsoon in north India, mature by mid-November and therefore facilitate the sowing of succeeding wheat crop which is not possible if traditional long duration pigeonpea varieties those mature in 8 to 9 months are sown. Recently, a high yielding pigeonpea variety "Pant Arhar–6" was developed by G B Pant University of Agriculture and Technology, Pantnagar was released and notified for cultivation in north and west India including the states of U.P. , Rajasthan, Punjab, Haryana, Delhi, Uttarakhand and plains of Jammu region. Pant Arhar–6 is not only high yielding but have resistance to major diseases and moderate resistance to important pest, the pod borer.

This new variety is developed through hybridization followed by pedigree method of selection from a cross between the genotypes ICPL 84023 and ICPL 88039. This variety can be grown under Rainfed / Irrigated conditions of *kharif* season .This variety yields 17-20 q/ha grains and matures in about 140-145 days and is suitable for pigeonpea - wheat cropping system. The grains of the variety are medium in size (test weight 8.11 g/ 100 seeds) and are of attractive reddish brown in colour. The dal of this variety is very delicious and nutritious having about 22 percent protein and cooked easily. For identification and certification purposes the salient characteristics of Pant Arhar–6 are summarised in Table 1 .

Production techniques of Pant Arhar-6 (PA 421)

Pigeonpea cultivation in Bundelkhand region is almost similar to the other parts of the country. Pigeonpea requires hot climate for growth. It can be grown in wide range of soils but generally loamy soils

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Table 1: Important Agro- morphological character of Pant Arhar-6

Character	
Growth habit	Indeterminate, erect
Flower Colour	Yellow with red streaks
Colour of mature pod	Dark brown
Seed Colour	Reddish Brown
Seed Shape	Oblong
Seed Size	Medium
Days to 50% flowering	90 -95 days
Days to maturity	140 -145 days
Plant height (cm)	200- 250 cm
No. of pods/plant	140 - 160
No. of seeds/pod	4
100 seed weight (g)	8.11

having good drainage are considered as best. Pigeonpea growth is severely affected in waterlogged soil. High yields can be obtained from pigeonpea field if proper cultural practices are followed to raise the crop. Cultural practices used to raise pigeonpea crop may vary slightly with the area of cultivation.

(i) Selection of Field/Land preparation: Well drained sandy loam to loam soil having neutral pH is considered as best for its cultivation. There should not be problem of waterlogging in the field. One ploughing followed by 2-3 harrowing + planking should be done. As pigeonpea is highly susceptible to waterlogging, it's sowing in ridges/raised beds is recommended in area receiving high rainfall. Sowing of pigeonpea in ridges/raised beds saves irrigation water as well as protect from adverse effects of waterlogging.

(ii) Seed Treatment: seeds before sowing should be treated with 2 g thiram + 1 g bavistin for one kg seed. To increase the nodule formation, seeds can be inoculated with Rhizobium + PSB + PGPR @ 20g each/kg seed.

(iii) Sowing Time: The proper sowing time of this variety is the II fortnight of June. Sowing should be done with the onset of monsoon in the area.

(iv) Seed rate and sowing depth: A seed rate of 12-15 kg/ha having good germination should be used. It is very important to note that seeds should not be sown deeper than 3-4 cm.

(v) Spacing: Row to row spacing for gwowing Pant Arhar – 6 should be kept at 45-60 cm whereas a plant to plant spacing of 15-20 cm be maintained.

(vi) Fertilizer doses & timing: For harvesting bumper crop proper fertilizers need to be applied at appropriate time in optimum doses. 100 kg DAP or 150 kg NPK mixture (12:32:16)/ha may be given as basal dose. In sulphur deficient soils, phosphorus should be applied through SSP.

(vii) Weed control- chemicals with doses & timing: The growth of pigeonpea in initial two months is very slow and the crop is infested by a number of weeds during this time and affect the crop health adversely. The yield losses due to the high infestation of weed may be as high as 30%. Therefore for proper weed control, Pendimethalin (3.3 lit/ha) dissolved in 500-600 lit of water should be sprayed as pre-emergence weedicide. If possible to avoid weed infestation in the field 2 hand weeding are required one at 25-30 Days after sowing and other at 45-50 Days after sowing.

(viii) Irrigation schedule: Generally, there is no need of irrigation in *kharif* season if rainfall is well distributed over the crop growing season. If there is moisture stress to ensure proper germination, one palewa irrigation is required. If required one light irrigation can be given at the time of flowering/ grain filling.

(x) Disease and pest control: Pigeonpea crop is attacked by a number of diseases and insect pests. *Phytophthora* stem blight is one of the major disease of pigeonpea and can causes severe yield losses if appear in early growing stages. The major symptom of this disease includes formation of brown to black, slightly sunken lesions on their stem and petioles. These lesions gradually girdle the main stem and under strong winds stem breaks at this point. To control *Phytophthora* stem blight generally seed treatment with Rodomil @ 5g/kg seed is recommended. Major insect pest of pigeonpea includes *Maruca* and pod borer. *Maruca* attacks the crop mainly at the flowering stages and form web like structure in flower clusters resulting in very less pod development. To control *Maruca* generally 2-3 sprayings of Indoxacarb @ 500 ml/ha or Fipronil @ 1lit/ha is recommended. Adults of pod borer lays eggs in developing flower buds, these eggs produce larvas which feed on developing seeds inside pods. To control pod borer Indoxacarb @ 500 ml/ha in 500-600 lit of water can be used.

(xi) Harvesting: Generally this variety becomes ready for harvest in 145-150 days. If crop is raised with modern techniques, grain yield of about 18 -20 q/ha may be obtained.

Pant Arhar-6 (PA-421) is a high yielding variety of pigeon pea and it is suitable for pigeon pea and wheat cropping system. With the adoption of proper production techniques, farmers can harvest 17-20 quintals from a hectare area and with the high yield potential variety is also having resistance against major diseases.

The discovery of agriculture was the first big step toward a civilized life.

- Arthur Keith

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The farmer works the soil, The agriculturist works the farmer.

- Eugene F. Ware

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Earth is here so kind, that just tickle her with a hoe and she laughs with a harvest.

- Douglas Jerrold

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It is impossible to have a healthy and sound society without a proper respect for the soil.

- Peter Maurin

Livestock: Panacea for zero based natural farming (ZBNF)

V. David Chella Baskar, Vishnu Kumar and Amit Tomar

Agriculture has been the backbone of the Indian economy for centuries. Nearly 58-60% Indian population depends on agriculture and allied sectors for their livelihood. In the light of the growing concerns about the sustainability of the current input-intensive agriculture system, the need for an alternative farming system has arisen. Among the various alternative farming models practiced across the world, Zero Budget Natural Farming (ZBNF) has recently come into the spotlight. Over the last few decades there has been a major transformation in the Indian agricultural sector. According to the Economic Survey, more than 1.6 lakh farmers are practicing the ZBNF in almost 1,000 villages using some form of state support, although the method's advocates claim more than 30 lakh practitioners overall. The original pioneer was Karnataka, where the ZBNF was adopted as a movement by a State farmers' association, the Karnataka Rajya Raitha Sangha. Large-scale training camps were organized to educate farmers in the method. According to a survey carried out in those early years, ZBNF farmers all owned small plots of land, had some access to irrigation and owned at least one cow of their own.

It was originally promoted by Maharashtrian agriculturist and Padma Shri recipient Subhash Palekar, who developed it in the mid-1990s as an alternative to the Green Revolution's methods driven by chemical fertilizers and pesticides and intensive irrigation. He argued that the rising cost of these external inputs was a leading cause of indebtedness and suicide among farmers, while the impact of chemicals on the environment and on long-term fertility was devastating. Without the need to spend money on these inputs or take loans to buy them the cost of production could be reduced and farming made into a "zero budget" exercise, breaking the debt cycle for many small farmers.Instead of commercially produced chemical inputs, the Zero Budget Natural Farming (ZBNF) promotes the application of *jeevamrutha* - a mixture of fresh desi cow dung and aged desi cow urine, jaggery, pulse flour, water and soil on farmland. This is a fermented microbial culture that adds nutrients to the soil, and acts as a catalytic agent to promote the activity of microorganisms and earthworms in the soil. About 200 litres of *jeevamrutha* should be sprayed twice a month per acre of land; after three years, the system is supposed to become self-sustaining. Only one cow is needed for 30 acres of land, according to Mr. Palekar, with the caveat that it must be a local Indian breed not an imported Jersey or Holstein.

The ZBNF method also promotes soil aeration, minimal watering, intercropping, bunds and topsoil mulching and discourages intensive irrigation and deep ploughing. Mr. Palekar is against vermicomposting, which is the mainstay of typical organic farming, as it introduces the most common composting worm, the European red wiggler (*Eisenia fetida*) to Indian soils. He claims these worms absorb toxic metals and poison groundwater and soil.

According to National Sample Survey Office (NSSO) data, almost 70% of agricultural households spend more than they earn and more than half of all farmers are in debt. In States such as Andhra Pradesh and Telangana, levels of indebtedness are around 90%, where each household bears an average debt of one lakh rupees. In order to achieve the Central government's promise to double farmers income by 2022, one aspect being considered is natural farming methods such as the ZBNF which reduce farmers' dependence on loans to purchase inputs they cannot

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afford. Meanwhile, inter-cropping allows for increased returns.The Indian Council of Agricultural Research is studying the ZBNF methods practiced by basmati and wheat farmers in Modipuram (Uttar Pradesh), Ludhiana (Punjab), Pantnagar (Uttarakhand) and Kurukshetra (Haryana), evaluating the impact on productivity, economics and soil health including soil organic carbon and soil fertility.

ZBNF is based on 4 pillars:

- **Jeevamrutha:**It is a mixture of fresh cow dung and aged cow urine (both from India's indigenous cow breed), jaggery, pulse flour, water and soilto be applied on farmland.
- **Bijamrita:**It is a concoction of neem leaves and pulp, tobacco and green chilies prepared for insect and pest management that can be used to treat seeds.
- **Acchadana (Mulching)** It protects topsoil during cultivation and does not destroy it by tilling.
- **Whapasa** It is the condition where there are both air molecules and water molecules present in the soil. Thereby helping in reducing irrigation requirement.
- **Other Natural Inputs:** ther mixtures are also used to manage insects and pests (natural pesticides and fungicides) using tobacco, green chili, garlic, neem and various fruits such as custard apple, guava, lantena camellia, papaya, white dhotara, pomegranate etc.

Mulching: ulching is also one of the Zero Budget Natural Farming four wheels. It is necessary to create the micro-climate under which micro-organisms can best develop, that is 25 to 32 temperature, 65 to 72% moisture and darkness and warmth in the soil. Mulching indeed conserves humidity of the soil (therefore diminishing the need for irrigation), cools it and protects its micro-organisms. Mulching with organic residues to reduce tillge, suppress weeds, promote humus formation and enhance the soil' water-holding capacity.

Table: Share of animals in total livestock (Per cent) in various districts of Bundelkhand region (2012)

District	Total No. of livestock (000)	% Share in total livestock			
		Cattle	Buffalo	Goat	Others
Banda	940	39.5	34.5	22.4	3.6
Chitrakoot	762	55.3	24.1	16.5	4.1
Hamirpur	793	34	25.2	36.8	4
Jalaun	804	28	31.9	33.4	6.7
Jhansi	954	37	25.5	30.8	6.7
Lalitpur	887	54.5	26.5	17.7	1.3
Mahoba	563	40.5	24.1	28.9	6.5
Uttar Pradesh	68715	28.5	44.6	22.7	4.2
Chatarpur	850	40.5	28.1	30	1.4
Damoh	797	70.1	13.4	15.3	1.2
Datia	364	29.5	41.3	27.4	1.8
Panna	693	59.8	20.5	18.1	1.6
Sagar	1165	68.9	18.3	12.1	0.7
Tikamgarh	868	42.3	26.7	25.8	5.2
Madhya Pradesh	36333	54	22.5	22.1	1.4

Source: Livestock Census District Wise Report 2012, Department of Animal Husbandry, Dairying and Fisheries, Ministry of Agriculture and Farmers Welfare, Government of India.

It is evident from the above table, the number of animals per household's shows that maximum number of cattle per households were in Chitrakoot (55.3%) followed by Lalitpur (54.5%) and Mahoba (40.5%) district during 2012. Whereas, in case of Bundelkhand region of MP the highest cattle population was observed in Damoh (70.1%) followed by Sagar (68.9%) and Panna (59.8%) districts. The maximum number of buffaloes was found in the district Banda followed by Jalaun and Lalitpur. However, in case of goatary maximum number per household are in Hamirpur followed by Jalaun and Jhansi districts. It could be inferred that the farmers of Chitrakoot and Damoh districts may follow ZBNF practice due to easily availability of farm yard manure. Similarly, it can be also utilized on large scale for production in bio-gas preparation. This paves the ways for maintaining the natural ecosystem for a long term perspectives.

In general, the crop residue provides 60-65% of fodder and its shortage in drought year is inevitable. Creation of fodder and feed block banks should be immediate priority. There is a scope to improve efficiency of zero based natural farming through utilizing the support of livestock and its output. This sort of farming will be much useful for sustainable utilization of natural resources. In order to overcome from farmers' suicides, indebtness and distress sale ZBNF will be much suitable system for enriching the fertility status of the soil as well. Natural farming focuses mainly on small communities and family settlements to which it ensures livelihood and self-reliance. It prevents small farmers of being totally dependent on firms and multi-national corporations that dominate the agricultural market of chemical inputs and seeds.

In the design of an appropriate policy on ZBNF, appropriate selection of crops and targeting of farmer households (small farmers' community practicing a low external input-based farming) need to be accorded priority in accordance with the agro-climatic condition of that particular region towards self reliance. At this juncture the governments and people have to be with the farmers by providing them the cost effective technologies and zero budget natural farming methods on sustainable mode. The centers of excellence at district/zilla level can be set up to enhance awareness on commercial aspects and socio-economic advantages of zero budget natural farming methods. Increasing the area and production under natural farming in future will lead to the goal of sustainable agriculture practices.

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- *Arthur Keith*

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The farmer works the soil, The agriculturist works the farmer.

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Earth is here so kind, that just tickle her with a hoe and she laughs with a harvest.

- *Douglas Jerrold*

Major fodder crops and their high yielding varieties for the Bundelkhand region

Indu[1], Subhash Chand[1*], Rajesh Kumar Singhal[1], Rakesh Choudhary[2] and Shahid Ahmad[1]

The Bundelkhand region covers about 7.2 million hectare area and is highly prone to drought. The major concerns in agriculture are water scarcity, land degradation, heat waves, erratic and unseasonal rainfall patterns and these factors tend to poor socio-economic status of farmers in this region. Livestock sector not only provides livelihood but also gives employment round the year to the rural youths. In this context, the major annual and perennial fodder crops, importance, quality attributes and their high yielding varieties for Bundelkhand regions have been described.

Rainfed agricultural system,particularly in semi-arid tropics, is highly vulnerable and unprotected due to thehuman-accelerated-climate change and socio-economic constrains on the growers. Climate change which is characterized in different categories of extreme events such as drought and heat waves,erratic and unseasonal rainfall pattern, prolongeddry spells, shifting length of growing period are being recognized in many regions of Indian subcontinent.

Bundelkhand region (23 8'- 26 31' N, 78 11'-81 30' E) spreads over 7.16 million ha in Central India including seven districts of Uttar Pradesh (Jhansi, Jalaun, Lalitpur, Hamirpur, Mahoba, Banda and Chitrakoot) and six districts of Madhya Pradesh (Sagar, Tikamgarh, Chhatarpur, Panna, Damoh and Datia). Average annual rainfall of these districts ranges 750-1100 mm. The region is prone to drought and tends to wide ranges of crop losses.This area is hotspot of water scarcity, land degradation and poor socio-economic status.Livestock sector is not only key component of rural livelihood but also provides round the year employment for rural youths and women. In this region, there is more livestock population with '*Gwari*' grazing system where cattle go to pasture lands and hilly areas from plains, and roam around to find food by themselves only (*Anna-pratha*).

By considering the above agro-climatic challenges in the region, the availability of fodder (green and dry) does not meet the actual livestock feed and nutritional demand. Poor nutritional quality and scarcity of cattle feed jeopardize livestock health and productivity, and their end-use-product quality such as milk and meat etc. In this regard, there are some important fodder crops which not only provide high fodder yield per se but also supply additional nutritional components to the livestock. These fodder crops can be utilized to the development of pasture land in the barren and unfertile lands of the region. These crops and their high yielding varieties are essential to combat the climate change and fulfill the basic demand of livestock sector in the Bundelkhand region. The major fodder crops and their varieties are briefly explained below.

Classification of fodder crops:

There are two major seasons *i.e. rabi* and *kharif* which can be effectively utilized by the farmers in the region. The widely accepted fodder crops in the *rabi* season are- oat and berseem, while in kharif are- maize, sorghum, pearl millet, BN hybrid, dinanath grass and cowpea.

Fodder Oat: Oat (*Avena sativa*L.) is widely grown in the winter season ofNorthern-India. It is a palatable, succulent and nutritious crop, and requires a long and cool season for its growth and development. Ideal sowing time is mid-October to November with seed rate of 80-100 kg/ha and requires 4-5 irrigations during the crop growth period. Harvesting is done at 50% flowering stage for single cut varieties and for multicut varieties, first cut at 60 days after sowing (DAS), second cut at 45 days

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after first cut and third cut at 50% flowering stage. Nutritional quality components are at peak when crop is harvested at 50% flowering stage which encompasses 10.0-11.5% crude protein (CP), 55-63% neutral detergent fiber (NDF), 30-32% acid detergent fiber (ADF), 22.0-23.5% cellulose and 17-20% hemicelluloses.

Fodder Berseem: Berseem(*Trifolium alexandrinum L.*) is most important leguminous fodder crop and also known as King of fodder due its availability up to 6-7 months as green fodder. Due to its leguminous nature, berseem has got potential for soil fertility and improves the physical, chemical and biological properties of the soil, tends to better plant growth and yield of crops in rotation and intercropping with non-leguminous crops such as cereals. In Bundelkhand region ideal sowing time is during mid-October with 25-35 kg/ha seed rate. Berseem can be intercropped with *rabi* maize, BN hybrid, and guinea grass. First cut can be taken at 55 DAS and subsequent cuts 25-30 days after each pervious cut. It encompasses nearly 17-22% CP, 42-49% NDF, 35-38% ADF, 24-25% cellulose, 7-10% hemicelluloseswhen harvested at 50% flowering stage of crop.

Fodder Bajra: Pearl millet (*Pennisetum glaucum* L.) is the most widely grown *kharif* crop in dryland, arid and semiarid areas of Indian subcontinent. It is well adapted to drought and heat waves, low soil fertility, high salinity and low rainfall. Ideal time of sowing in *kharif* season is mid-July to August after commencement of rain with seed rate of 10-12 kg/ha. Pearl millet goes well with cowpea as intercrop. For single cut varieties harvesting can be done at 55-60 DAS, and for multicut varieties, first cut at 40-45 DAS are suitable and subsequently at 30 days of interval. It contains 7-10% CP, 50-58% i*n vitro* dry matter digestibility (IVDMD), 56-65% NDF, 38-40% ADF, 30-35% cellulose 15- 25% hemicelluloses when harvested at 50% flowering stage of crop.

Fodder Sorghum: Sorghum (*Sorghum bicolor* L.) is an outstanding crop grown throughout the country. It is very hardy crop and a better option in places where maize cannot be grown. Being more palatable and nutritious, it can be fed as dry, green or as a straw to the animals. In rainfed areas sorghum cultivates during kharif season in the month of June-July with recommended seed rate of 35-40 kg/ha. Forage sorghum intercropped with cowpea and guar. The crop should be harvested at 60-75 DAS in single cut varieties. For multicut varieties, harvesting has to be done for first cut at 40-45 days and subsequent at 30 days of intervals. It should be remembered that harvesting should not be done during first 30 days since the sowing due to high amount of anti-nutritional factors in early stages. It accommodates about 9-10% CP, 65-65% NDF, 37-42% ADF, 32% Cellulose, 21-23% Hemicelluloses.

Fodder Maize: Maize (*Zea mays* L.) is one of the most versatile crops with wider adaptability under varied agro-climatic conditions. It is an ideal forage crop grown in all seasons throughout the country. It is fast growing, moreregeneration capacity and high yielding crop, and provides nutritious feed to the cattle which can be fed at any stage of growth without any risk to animals. Maize is an excellent forage crop for silage purpose and can be used during lean period. Ideal time of sowing in *kharif* season is mid-July to August with seed rate of 40-50 kg/ha.Maize is intercropped with cowpea. The crop is ready for harvest at silk stage (60-75 DAS) for fodder purpose, which goes up to milk stage. It encompasses 9-10% CP, 60-64% NDF, 38-41% ADF, 28-30% cellulose, 23-25% hemicellulose when crop is harvest at 50% flowering stage.

Fodder Cowpea: Cowpea (*Vigna unguiculata* L.) is a quick growing leguminous forage crop. It is usually grown as mixed crop with cereal fodders and grasses. The ideal time of sowing in *kharif* season is mid-July-August with seed rate of 35-40 kg/ha for its proper plant population. Harvesting is done after 50-60 DAS at 50% flowering stage. Summer cowpea crop requires few more days and should be harvested at 70-75 DAS. It holdsnearly 20 -24%CP, 43 -49%NDF, 34 -37%ADF, 23-25% cellulose, 5 -6% hemicelluloses.

Bajra-Napier (BN) Hybrid: BN-hybrid (*Pennisetum glaucum* × *P. purpureum.*) is very significant perennial fodder crop because of its round the year availability of fodder, high yield, and increased palatability and digestibility. It can withstand high temperature and dry spells. BN propagates through vegetative cuttings (rooted slips) and in rainfed areas best time of sowing is in the month of July-August after receiving first rainfall with around 35000 rooted slips/ha. BN hybrid suitably intercropped with leguminous crop *i.e.*, berseem, cowpea and lucerne. First cut after 60-65 DAS and subsequently after 30 days of interval. Fodder quality attributes of BN Hybrid are 8.7-10.2% CP, 63-64% NDF, 43-44% ADF, 55.6% IVDMD.

Guniea Grass: Guniea grass (*Panicum maximum* Jacq.) is the most productive, perseverance and tall forage perennial grass for tropical region. It can use as green fodder, green-silage and hay. Ideal time of establishment is mid-February to July with seed rate of 3-4kg/ha. It can also be propagated through rooted slip (40000 kg/ha). Ideal time of harvesting is at 75 DAS and subsequently after 45 days of interval. Guniea grass can give 6-7 cuts in a year. It contains 7-13% CP, 65-77% NDF, 51-52% ADF, 65-69% IVDMD at 50% flowering stage.

Dinanath Grass: Dinanath grass (*Pennisetum pedicellatum* Trin.) is annual fodder crop with profuse tillering and good herbage quality with high yield. It thrives very well into hot and humid climate. Ideal time of sowing is mid-June to July with recommended seed rate of 3-4 kg/ha. Intercropping can be done with leguminous crops such as cowpea and guar. It encompasses 7.4% CP, 70-75% NDF, 45-50% ADF at 50% flowering stage.

Anjan Grass: Anjan grass (*Cenchrus ciliaris* L.), also known as buffel grass and dhaman grass, thrives well in hot and humid climate. It is highly drought tolerant and well adapted to arid and semi-arid areas. Among the twenty species, *C. ciliaris* and *C. setigerus* are most commonly used for forage production. Ideal time of sowing is rainy season (mid-June to July) with recommended seed rate of 5 kg/ha. It contains 7-9% CP, 68-70% NDF, 50% ADF, 60-62% IVDMD.

***Pennisetum* Hybrid:** It is aninterspecific hybrid of *Pennisetum glaucum* × *Pennisetum squamulatum*. The interspecific hybrid (ISH) is perennial in nature, multi-tillered, multicut, stress tolerant and suitable for cultivation in rangeland and rainfed conditions. It is propagated through rooted slips during *kharif* season. Fodder quality attributes of *Pennisetum* Hybrid are- 7.35% CP, 66.5% NDF, 40.0% ADF, 53.0% IVDMD.

Important fodder crops and their high yielding varieties:

Sr. No.	Varieties	GFY (t/ha)	DMY (t/ha)	Seed Yield (q/ha)
Fodder Oat				
1.	Kent (SC)	45.0	9.7	12.0
2.	Bundel Jai-822 (MC)	44-50	9.5	14.0
3.	Bundel Jai-851 (MC)	47.0	8.2	12.0
4.	Bundel Jai-2009-1 (SC)	53-62	12-13.6	20.0
5.	OL-1869-1 (SC)	50.0	9.1	21-23
6.	OL-1861 (SC)	53.0	9.7	22-24
Fodder Berseem				
1.	Wardan (MC)	65-70	13.9	4.8
2.	Bundel Berseem -2 (MC)	90-100	8.5-10.5	4.3
3.	Bundel Berseem-3 (MC)	68-83	9.0	3.8
4.	JBSC-1 (SC)	30.2	6.0	8.0
Fodder Bajra				
1.	Avika-Bajra-Chari-(AVKB-19, SC)	37.0	8.8	10.2
2.	NDFB-5 (Dual)	50.5	10-11	22.5
3.	NDFB-11 (SC)	52.5-54.0	10-11	15-20
4.	BAIF-Bajra-1 (MC)	38-40	8-9	-

Fodder Sorghum				
1.	UP Chari-1	33.0	8.0	-
2.	UP Chari-2	38.0	7.0	12.5
3.	MP Chari	64.5	12.5	4.5-5.5
4.	Jawahar Chari-6	70.6	20.3	5.0-5.6
Fodder Maize				
1.	African Tall	50.0	15.5	30
2.	J-1006	43.0	12-13	65
3.	PratapMakka Chari-6	35.0	10-11	38
Fodder Cowpea				
1.	Kohinoor	36	6.0	5.0
2.	Type-2	33.0	5.0	12-16
3.	UPC-5287	36	6.3	-
4.	Bundellobia -1	30-35	4-5	6.5
5.	Bundellobia -2	35	3.5-4	6.0
6.	Bundellobia -4	30	5.1	6.9
BN Hybrid				
1.	BNH-10	130	26	Rooted slips
2.	CO (BN) 5	90	20-22	Rooted slips
3.	PBN-351	130	25	Rooted slips
4.	TNCN-1280	100	20-22	Rooted slips
5.	Hybrid-3 Napier	70-80	18-20.5	Rooted slips
Guniea Grass				
1.	Bundel Guniea-1 (MC)	65	13.5	5-8
2.	Bundel Guniea -2 (MC)	65	16	5-8
3.	Bundel Guniea -4 (MC)	80	18	5-8
Dinanath Grass				
1.	Bundel Dinanath-1 (SC)	34.5	6.2	3.4
2.	Bundel Dinanath-2 (SC)	37.5	6.8	3.4
Anjan Grass				
1.	Bundel Anjan 1 (MC)	41.0	9.35	0.8
2.	Bundel Anjan 3 (MC)	37.0-40.0	8.0-9.0	1.2
3.	Bundel Anjan 4(MC)	37.5	13.7	1.0-1.3
Dhaman Grass				
1.	Bundel Dhaman-1(MC)	13.5-14.8	2.3-4.9	-
Pennisetum Hybrid				
1.	Bundel Bajrasquamulatum hybrid-1 (BBSH-1) (MC)	33.4	9.4	Rooted slips

Livestock sector is a major component of farm income and increasing trend in livestock growth will likely to put greater pressure on fodder production in Bundelkhand region. The adoption of high yielding and nutritionally rich varieties will not only increase the farmersincomebut also complete the nutritional demands of the livestock in Bundelkhand.

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