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Diversified agriculture for higher productivity and profitability–A review

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ABSTRACT

In the present scenario of food production system, one of the most important challenges the Indian agriculture facing today is how to sustain farm profitability and food security. In order to feed an increasing the population 2% per year and meet the food demand (341 million tonnes by 2025), the agricultural productivity and growth need to be sustained and further improved. Food security is multidimensional crisis, which directly hits the poorest and neediest and in turn decreases their already low quality of life. The agriculture sector is the starting point for finding sustainable solution to overcome the food crisis. This situation is nodding towards rethinking about the profitable agriculture. For this concern holistic approaches have to be continued with certain aspects so that the 60–70% population associated with agriculture remains in the profession. Else wise, everyone wants to have alternate entrepreneur rather than agriculture since it is less profit oriented with high risk and needs more hard work as compared to other entrepreneurs. Diversified agriculture is an integration of several crops and livestock's, in production system for a higher food production and farm profitability.

Key words: Agriculture, Diversification, Livestock, Fisheries, Poultry, Profitability.

The food grain production increased from 50.80 million tonnes in 1950-51 to 273.38 million tonnes in 2016-17 (Economic Survey 2016-17). There have been several agricultural technologies namely; agronomic practices, soil and water management, use of high yielding varieties, insect pest control strategies etc. that led to increased food grain production from the relatively less per capita land availability in the country. After the 'Green Revolution', the food grain production has shown a plateau, due to fatigued soil system to achieve higher yield despite improved crop cultivars, use of fertilizers and pesticides. Despite increase in food grain production, the targets for the same are increasing year after year due to increasing population (about 2% every year). Also, increasing long term productivity of agro-ecosystem is paramount importance for food and nutritional security of the country (Meena *et al*., 2016). The NITI (National Institution for Transforming India) Aayog has set a target of 307.5, 29.5 and 58.65 million tonnes of cereals, pulses and oilseeds, respectively. To meet this target there is need to enhance pulse and oil seeds production by 18.5 and 38.5 million tonnes, respectively. However, according to the National Academy of Agricultural Sciences, India would require 300.5 million tonnes food grains, 40.5 million tonnes oilseeds by 2025. Will India be able to achieve these targets?.

This situation is nodding towards rethinking about alternate agriculture production system; diversified agriculture can improve resilience in a variety of ways: by engendering a greater ability to suppress pest outbreaks and dampen pathogen transmission, which may worsen under future climate scenarios, as well as by buffering crop production from the effects of greater climate variability and extreme events (Lin, 2011). Moreover, all the nutrient requirements of human are not exclusively found in single food, to meet such requirement different food stuffs have to be consumed by farmers. Such requirement can be fulfilled by adopting diversified agriculture production system at farmer level, enabling different enterprises such as agricultural diversification, livestock, fisheries, poultry and agroforestry for higher productivity and profitability. Now, farmers have been looking for some better alternative to diversify, contingent upon their hardy nature and higher returns, medicinal plant cultivation is a better option (Kalaichelvi and Swaminathan, 2009). More diverse agro-ecosystems with a wider range of traits and functions will be better able to perform under peculiar situation (Matson *et al*., 1997). Diversified agriculture is a strategy to maximize the use of land, water and other resources and for the overall agricultural development in the country (Acharya *et al*., 2011). Integration of different enterprises provides flow of money round the year amongst farming community, which is important to protect crop productivity against environmental change. Hence, in this paper we tried to review all the aspects related to diversified agriculture and other enterprises to ensure higher productivity, profitability and livelihood for marginal and small farmers'.

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AGRICULTURAL DIVERSIFICATION

In general, most of the farmers get involved in at least two or three entrepreneurship, which are interrelated e.g. animal husbandry along with agriculture is perhaps the most primitive system since inception of agriculture. Now-a-days this system has many more opportunities such as dairy, poultry, piggery, goat and sheep raring, vegetable cultivation, fisheries etc. and these systems provides additional and regular income to the farmers. Many of these entrepreneurs survive on the bi-product of others. A study involving the integration of crops with fish, poultry, pigeon and goat (Table 1) resulted in higher productivity, higher economic return of ₹ 1,31,118 (mean of 3 years). Integration of enterprises created the employment opportunity for 576 man days annum^{-1} in comparison to 369 mandays annum^{-1} generated in cropping alone system, cropping with fish and goat created additional 207 mandays annum^{-1} (Jayanti *et al*., 2001). The resources were recycled in such way that fish were fed with poultry, pigeon and goat dropping.

Monoculture system relay mainly on external inputs, while integrated farming system, recycling of nutrients takes places that helps in reducing the cost of production for economic yield. Rice + *Azolla*–cum–fish culture is one of the economical options for diversified agriculture or integrated farming system. The gross income obtained was 25.7% higher in rice+ *Azolla*+ fish and 6.9% higher in rice + fish over rice crop alone (Table 2) and the net income was also followed same trend. This model was proposed for extensive scale adoption in Tamil Nadu (Balusamy *et al*., 2003) for higher profitability and livelihood of small and marginal farmers. Another study conducted (Gill *et al*., 2009) at ICAR–PDFSR, Modipuram for ascertaining the livelihood security of marginal and small farmers under irrigated eco-system advocated the beneficial effect of integrated farming system. The model developed on 1.5 ha area comprising the crops (0.72 ha), dairy (0.32 ha), horticulture (0.22 ha), Indian fishery (0.10 ha), and Indian apiary (0.14 ha). The highest returns (₹ ha^{-1}) was from crops followed by dairy, horticulture, fishery and apiary (Table 3). The relative contribution from dairy, horticulture, fishery and apiary towards net returns was 52, 14, 3 and 6% where crops were taken as 100% respectively. Thus, in this system component crop showed higher contribution compared to other components. A farming system based on different enterprises *viz*., dairy, poultry and sheep rearing clearly revealed that all the farming system generated more than 3 fold additional employments over arable farming (Radha *et al*., 2000). Net returns (₹ ha^{-1}) were higher in agriculture+ dairy (₹ 35,293) followed by agriculture + poultry (₹ 26,830) and agriculture +sheep rearing (₹ 14,665). Among the various farming systems, agriculture+ dairy proved to be more profitable than other farming systems (Table 4).

CROP DIVERSIFICATION

The opportunity for crop diversification emerge from technological breakthroughs, changes in demand pattern, development of irrigation, availability of marketing infrastructure and new trade provision. In Indian agriculture to attain profitability and balanced economic development, crop diversification is essential through technologically

Table 3: Net return and relative profit margin of 1 ha module of farming system.

Enterprises	Net return (₹ ha^{-1} annum^{-1})	Relative Profit margin (%)
Crops	53,183	100
Dairy	27,515	52
Horticulture	7,168	14
Indian Fishery	1,445	3
Indian Apiary	3,370	6
Total	92,681	–

Source: (Gill *et al*., 2009)

Table 1: Productivity and economic analysis of integrated farming system in Tamil Nadu (mean of 3 years)

Farming systems	Systems rice equivalent yield (t ha^{-1})	Net return (₹ ha^{-1})	B:Cratio	Per day return	Employment generation (Man days)
Cropping alone	13.0	37,153	2.43	178	369
Cropping +fish+ poultry	29.6	97,731	3.02	400	515
Cropping +fish +pigeon	29.2	98,778	3.06	400	515
Cropping+ fish +goat	37.7	1,31,118	3.36	511	576

Table 2: Economics of rice-*Azolla* fish integrated farming system.

Systems	Gross income (₹)			Total expenditure (₹)	Net income (₹)
	Crop	Fish	Total		
Rice	43,291	–	43,291	20,320	22,971
Rice + fish	39,447	11,422	50,869	22,300	28,569
Rice + *Azolla* +fish	40,447	13,649	54,401	22,613	31,788

Source: (Balusamy *et al*., 2003)

Table 4: Income and employment generation under different farming systems of northern Telengana state.

Farming system	Human labour (MWDs)	Net returns (₹)	Additional employment over agriculture (MWDs)	Additional net return over agriculture (₹)
Agriculture + dairy	521	35,293	359	27,842
Agriculture+ poultry	528	26,830	366	19,379
Agriculture +sheep rearing	486	14,665	324	7,241
Agriculture alone	162	7,451	-	-

MWD: Man working days Source: (Radha *et al*., 2000)

feasible and economically viable enterprises. In fact, it is one of the important options for poverty eradication.

Major driving forces for crop diversification: There are major driving forces for crop diversification are: (1) Increasing income on small farm holdings, (2) Withstanding price fluctuation, (3) Mitigating ill-effects of aberrant weather, (4) Balancing food demand, (5) Improving fodder for livestock animals, (6) Conservation of natural resources (soil, water, etc.), (7) Minimizing environmental pollution, (8) Reducing dependence on off-farm inputs, (9) Decreasing insect pests, diseases and weed problems and (10) Increasing community food security.

Priorities for crop diversification: The major priorities for crop diversification in terms of increasing of resource use efficiency through adoption of crop rotation, integration of crops and on farm available technologies under changing weather condition and price fluctuation for nutritional and food security issues. Crop diversification aims from low value to high value crops; water loving crop to water saving crop; single crop to multiple crops/mixed cropping; crop alone to crop with livestock-fish-apiculture; agriculture production to production with processing and value addition to achieve maximum benefits. It is time to critically re-design alternative cropping based on agro-climatic zone and specific crop in order to have efficient utilization of natural resources and also stabilize the production and profitability.

Cereal based crop diversification: As it is well known that rice-wheat system is the most dominant cropping system that occupies about 10.5 million ha area and spread over many states *viz.* Uttar Pradesh, Punjab, Haryana, Madhya Pradesh and West Bengal. About 75% of food requirement is met by rice- wheat cropping system. However, productivity of these crops is low as compared to China, which excels in yield levels (Fig.1) of crops such as rice, wheat, maize, groundnut, soybean, pulses and cereals (Economic Survey, 2015–16). Now non proportionate increase in food grain production resulted in soil fatigue caused intensive cultivation in irrigated areas, yield stagnation of high yielding varieties, loss of Indian land races, water logging, incidence of new insect pests, and ultimately decline in farm income. To meet out such situation, there are about 30 cropping systems (Table 5) which have been identified as most economic for the country of different agro-eco regions (Yadav *et al*., 1996). Crop diversification is a major component of diversification in agriculture and significantly higher yield in terms of rice equivalent yield (16.1 t $ha^{-1}year^{-1}$) with inclusive of vegetable pea as pre-rabi crop, late sown wheat followed by greengram during summer in highly intensive sequence (rice-vegetable pea-wheat-greengram) compared to rice-wheat sequence (12.9 t ha^{-1}) (Gill and Ahlawat, 2006). It also recorded higher system productivity (44.2 kg ha^{-1} day^{-1}) with additional income of ₹ . 5471/- over rice-wheat system (Table 6).

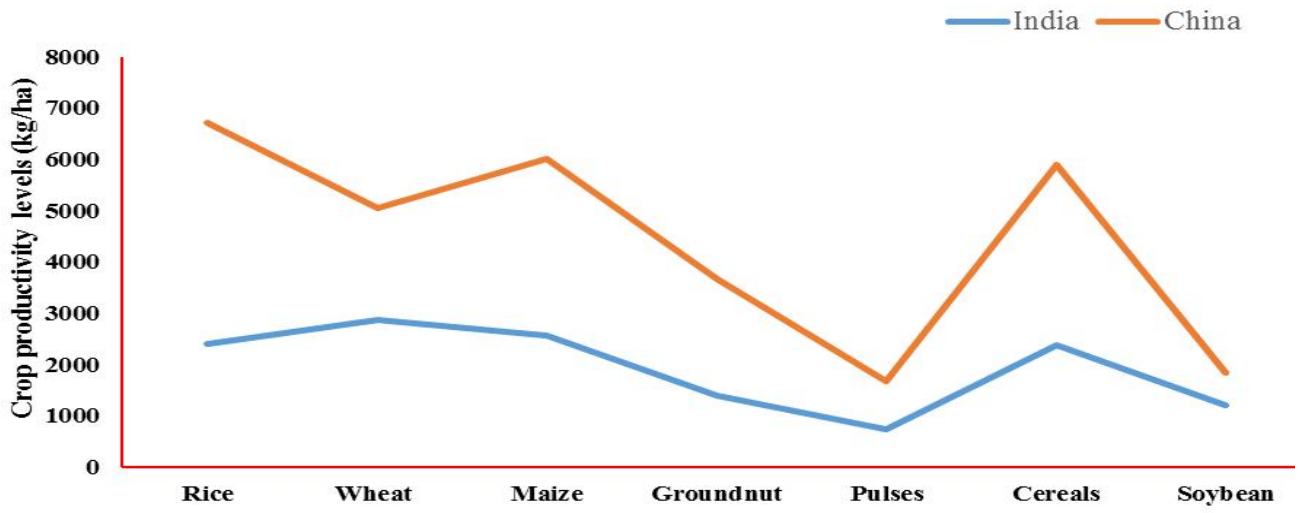


Figure 1: Crop productivity levels of some of selected crops in India and China during 2014-15

Table 5: Cropping system prevalent in different agro-eco regions.

Eco-system and Name	Soil type	Cropping system
Arid – Eco system		
Western Himalaya	Shallow skeletal	Maize- wheat, pea/cabbage/potato/ cauliflower - millet – red clover
Western Plain	Saline soils	Cotton-onion/ napier, perlmillet hybrid/ fodder sorghum/maize – wheat – cowpeas (f), pearlmillet – potato – pearlmillet
Deccan plateau having hot climate	Red and black	Maize- gram, hybrid cotton – sunflower, pearlmillet/ groundnut – sorghum - gram
Semi-arid Eco-system		
Northern plain and Central highlands	Alluvium derived soil	For parts of RajasthanBajra/maize – wheat, millet – wheat- mung bean, cluster bean – barley. For parts of Punjab and U.P. Rice – wheat, rice – wheat – cowpea, sugarcane – wheat, For parts of M.P Jowar wheat
Malwa highlands and Gujarat plains	Medium to deep black soil	Groundnut – whet – green gram, soybean – wheat – green gram , soybean – wheat -fallow
Deccan plateau having semi-arid climate	shallow to deep black soil	Sorghum-wheat, cotton-sorghum, green gram-rabi sorghum-wheat
Telengana plateau and Eastern Ghats	Red & black	Rice-rice, rice-groundnut, rice-black gram/ green gram
Eastern Ghats, T.N. uplands and Red loam soils Karnataka plateau	Red loam soil	Wet land rice: rice-rice-pulseGarden lands: rice-groundnut-pulse
Sub-humid Eco-system		
Northern plains	Alluvium derived	Rice – wheat, Rice – wheat-green gram/ green gram/ cowpeas, rice-sunflower/ gobhi sarson/ sugarcane-wheat
Central highlands	Black and red	Cotton-wheat, soybean-wheat, sorghum-gram-fallow
Eastern plateau gram	Red & yellow	Rice-gram, Rice – wheat/black gram/ green
Chhotanagpur plateau and eastern ghats rice-groundnut	Red lateritic	Rice – wheat, arhar+groundnut/black gram,
Eastern plain	Alluvium derived	Rice – wheat, Rice – maize, Rice – sugarcane+coriander/leafy vegetables, rice-potato/tobacco
Western Himalaya with warm sub-humid climate	Brown forest & podzolic soils	Maize-wheat, Rice – wheat, millets-potato/ tomato/capsicum
Humid-per humid Eco-system		
Bengal and Assam plains	Alluvium derived	Rice – wheat, Rice – mustard-riceIn Diara area: potato/rajmash-rice, sweet potato-rice, rice-buckwheat/niger
Eastern Himalayas	Brown and red hill soil	Rice-sugarcane, rice-potato/sweet potato/ mustard/sesame, maize-rajmash
North-eastern hills	Red lateritic	In valley areas: Rice –mustard/blackgram/ green gram/lentil, jute-pulse/oilseedsIn Hilly areas: maize-potato, millet-pulses
Coastal Eco-system		
Eastern coastal plains	Alluvium derived	Rice-groundnut, rice-rice-blackgram, rice-vegetables/cowpea/cauliflower
Western Ghats and coastal plain	Lateritic & Alluvium derived	Rice (autum)-rice-cowpeas/green gram/ black gram/ sesame/ groundnut, rice-pulses
Island Eco-system		
Island of Andaman and Nicobar and lakshadweep	Red loamy and sandy soils	Rice-sesame/bhindi/cowpea, rice-rice-cowpea (f), rice-rice-green gram/black gram/sesame/ groundnut, rice-tomato/groundnut.

Source: (Yadav *et al.*,1996)

Table 6: Effect of crop diversification on productivity and profitability of rice-wheat system

Cropping sequences (3 years)	REY (t $ha^{-1}year^{-1}$)	Productivity (kg ha^{-1} day^{-1})	Net returns (Rs/ha/year)	IWUP (kg grain $ha^{-1}cm^{-1}$)	NUE(kg grain kg^{-1} nutrients)
T1-Rice-Wheat Rice-Wheat Rice-Wheat	12.86	35.23	37899	115.54	26.2
T2-Rice-Berseem(Fodder) Rice-Wheat Rice-Wheat	13.61	38.38	42768	115.93	31.4
T3-Sorghum(Fodder)-Wheat Greengram- Rice-Wheat Rice-Wheat	13.33	36.52	43148	132.90	28.5
T4-Rice-Mustrad-Greengram Rice-Wheat-Greengram Rice-Wheat-Greengram	15.47	42.38	49857	155.32	27.8
T5-Soybean-Wheat Rice-Wheat Rice-Wheat	12.78	35.01	39172	128.05	28.0
T6-Rice-Vegetable pea Wheat-Greengram Wheat-Greengram-rice Vegetablepea-Wheat Greengram	16.12	44.16	43370	143.67	22.9
CD(P=0.05)	0.71		2131		

*REY- Rice equivalent yield; IWUP-irrigation water use productivity; NUE-nutrient use efficiency
Source:(Gill and Ahlawat, 2006)

Oilseeds based crop diversification: India ranks at fourth in vegetable oil economy, though being third largest importer of world. Despite that the per capita oil consumption of only 11 kg $year^{-1}$ is considerably lower than the most developed countries. Palm and soybean oil constitutes half of the consumption followed by mustard, groundnut, cotton seed oil, rice bran oil and safflower oil. Oilseed production is characterized by low yield since these are grown on marginal and sub marginal poor fertile lands under low input uses under rainfed condition. In India average productivity of oilseed is 970 kg ha^{-1}, which is half of world's average. Oilseed need to be enhanced to meet the national shortfall, as the current per capita consumption edible oil level of India at 18.3 kg $year^{-1}$ for 2014–15 is much lower than global averages 24 kg $year^{-1}$ (Economic Survey, 2015–16). To meet the vegetable oil requirement of our burgeoning population at optimum level, we have to increase our production from present level of 20 million t to about 50 million t by 2020 A.D. (Hegde, 2005). Farmers have to focus on productivity rather than increasing merely area. Also better productivity has to be realized through value added products from oilseed. Through these efforts if we are able to increase the productivity by 100 kg $year^{-1}$ every year, *i.e.* from 900 to 1400 in five years, the country will be able to meet out the demand of vegetable oils thus reducing the import (Mehta, 2007). Crop diversification through oilseed based production system groundnut and soybean are most suited to be grown in many cropping system sequence. The reason being groundnut is grown mainly in Andhra Pradesh, Maharashtra, Gujarat and Rajasthan. In fact, groundnut and sorghum was grown simultaneously in similar climate belts having moisture deficit varying 0–40%. Shorter duration varieties of these crops are urgently needed to be fitted in intensive crop rotations. Soybean is ideally suited for vegetarian dominated Indians society. It is also called poor man's meat. It fits efficiently in cropping pattern replacing some efficient *kharif* crops. Also, energy rich crop such as groundnut, rape seed and mustard, soybean, sunflower, castor, safflower, sesame, linseed and niger must find place in cropping systems. In India, oil seed occupies 26 million ha area with a production of just 25 million tonne which remove about 3 million tonne of nutrients. However, hardly 0.5 million tonne of nutrients is added to oilseed crops through fertilizers resulting in a huge gap of 2.5 million tonne. Thus oilseed production without fertilizer additions would not be possible. But alone fertilizer additions hold promise of doubling production thus enhancing profitability (Biswas and Das, 1999).

Another aspect of oilseed production is to evaluate and improve the crops and varieties to produce oils that can be used as bio-fuel. In this context bio-diesel and bio-ethanol has emerged as the most suitable renewable alternatives to fossil fuel as their quality constituents match diesel and petrol respectively. India is a huge importer of crude oil and spends ₹ 1200 billion of foreign exchange every year to meet 75% of its needs. India has a potential of collecting 5 million tonne of tree-borne oilseeds of which only 0.1–1.0 million tonne is being utilized presently (Kumar, 2003). Moreover,

there is about 60 million ha of wasteland of which 50% can be suitably utilized for growing plantations of biofuel plants like jatropha that can produce 200 liter of biodiesel per year after the initial three-year period of establishment (Ghaisas, 2005). India ranks fourth after Brazil, U.S and China in ethanol production from bio-resources. Also India is fifth largest consumer of fossil fuel in the world after China, Japan, Russia and US. However, we have already started a National Mission on Bio-diesel with a view to find a cheap and renewable liquid fuel based vegetable oils (Shukla, 2005). India has reached a decisive stage to make a blending of 5% with conventional diesel at some selected districts (Behl, 2006). India produced 1749 million liter of ethanol in 2004 mainly from sugarcane (Peterson, 2006). Thus ethanol production can be increased further by using other crops like sweet sorghum, sugar beet, sugarcane juice and potential feed stock options. Other potential sources of ethanol can be cellulosic energy crops and crop residues as well as other waste products high in cellulose. Cropping system with castor in monsoon and sweet sorghum in winter, in certain areas, has been found to yield promising returns under irrigated and rainfed situations. Similarly, India is the world's leading producer of castor and first in world to exploit hybrid vigor in the crop on commercial scale.

Pulses based crop diversification: Indian population is predominately vegetarian and protein requirement is mostly met from pulses. Apart from human diet, pluses form an important fraction of cattle feed and fodder as hay, green fodder and concentrates, etc. Being leguminous, the pulse plants take so little and give much more nitrogen to our soil to companion or succeeding crops. Thus every pulse plant is a mini fertilizer plant itself. Major pulses such as chickpea, pigeonpea, peas, urdbean, greengram and minor pulses like chuckling pea, horse gram, lentil and moth bean are grown under rainfed condition. These pulses are subjected to multiple stresses such as drought, high and low temperatures, high solar radiation, salinity and water logging. Adverse situation will be more pronounced, if the present trend in climate change will continue as projected through various weather prediction models. However, to cope with such adverse abiotic factors, pulses have wide adaptive mechanism such as deep rooting system, high degree of dehydration tolerance, phenotypic plasticity, wide ranging sensitivity towards photo-thermoperiods and higher moisture retention capacity. Pulses are the important crops for diversification in rice-wheat system. These can help to replenish soil fertility and increase productivity of the system. Pulses have been reported to fix atmospheric nitrogen in the soil up to 30 kg ha^{-1}. Crop diversification with short duration pulses (urdbean and mungbean) has been considered as one of the important options, it can help in reversing the process of system degradation and can deliver many agronomic and ecological benefits simultaneously, while maintaining or enhancing the scale of efficiency of production (Gill *et al*., 2007). Pulses have tremendous scope for area expansion. Short duration varieties of pulses can fit well in various cropping systems. About 2.5 Million ha additional area can be brought under different pulses through cropping system manipulation. Mungbean and urdbean could be grown as catch crop in summer/spring under cereal-based cropping systems of IGP, intercropping short-duration pulses (mungbean, urdbean, and cowpea) in sugarcane, millets cotton, etc. Another option is to advocating new cropping systems such as pigeonpea–wheat in the north, rice–lentil in the east and urdbean–rice in the southern peninsula. Out of 10.5 Million ha rice fallows of eastern (Uttar Pradesh, Bihar, West Bengal, Assam), Central (Chhattisgarh) and southern states (Andhra Pradesh, Karnataka, Tamil Nadu), 2.5 Million ha can be utilized by expanding area under lentil, mungbean and urdbean cultivation. In rice-wheat system, the farmers mainly grow green gram or black gram in the niches available between the two crops. Mainly, farmers grow green–gram and *Sesbania* (*Dhaincha*) crops after the harvesting of wheat crop and incorporate in-situ before the transplanting of rice crop. Green gram is used for dual purpose *i.e*. for seed harvesting and green manuring. Greengram is also taken by some growers after harvesting of potato and sugarcane.

LIVESTOCK, FISHERIES, POULTRY PROMOTION For BALANCED GROWTH

Animal husbandry is the major subsidiary occupation being practiced by an almost every farm family in the area and livestock based integrated farming system is one of the rising agriculture systems for the developing countries. Livestock provide a valuable source of food and play important agricultural and cultural roles in societies (FAO, 2009). A large number of landless families earn their livelihood mainly from livestock (mainly buffaloes, cows, goats, camels and bullocks) rearing. Currently, livestock is one of the fastest growing agricultural subsectors in developing countries. This growth is driven by the rapidly increasing demand for livestock products, now, this demand being driven by population growth, urbanization and increasing incomes in developing countries (Delgado, 2005). Livestock and other enterprises like fisheries, poultry are acts as a cushion against income shocks arising due to crop failure in abnormal situation. But the problem that are encountered includes– huge unproductive population due to unavailability of fodder as well as poor genetic makeup of livestock's. During the forage shortage, straw is fed to livestock either alone or mixed with a small supplement of green forage and generally without any concentrates or very less protein content. It has long been established that rice straw has low protein (3–5%), calcium (0.25– 0.55%), phosphorus (0.02–0.16%) but is high in crude fiber (26–34%) and silica (12–16%) with slightly lower lignin than other cereal straws (Jackson, 1977). Therefore, proper utilization of the feed ingredients is must

for higher milk production (Ahmad *et al*., 2011). Good quality feed supplement has not only improved the productivity of animals but also improved the quality of animal produces (Niwas *et al*., 2012). Other problems include incidence of different contagious diseases like foot and mouth disease, hemorrhagic septicemia, foot and mouth disease (FMD) and black quarter, pox and peste des petits ruminants (PPR) in sheep and goats that affect both productivity and animal production. Therefore, different strategies to cope these problems must be made popularized and finally be adopted by the farmers. Thus, fodder production from fodder trees and grasses need to be enhanced from community controlled areas as well as private lands. Besides this efficient use of agricultural residues treatment for quality improvement need to be focused. Surplus residues produced at certain location needs to be supplied to other locations rather than burning them. Scientific animal breeding programmes need to be adopted for enhanced productivity of animals. Since improved breeds are more prone to diseases and can not be sustained without health care services. Small livestock such as rabbit, goat, and poultry has been an important source of immediate cash income especially for small and marginal farmers (Kristjanson *et al*., 2004) and also livestock rearing is an important pathway out of poverty (Randolph *et al*., 2007; Peacock, 2005). Farming with livestock rearing is generally better off than those who depend entirely on crop agriculture (De Haan *et al*., 2001). Small livestock often require less start up capital and can easily be raised even by small and marginal farmers with limited land resources. Many development organizations in rural areas promote rearing of small livestock to improve the income and nutrition status of the resource poor farmers (Randolph *et al*., 2007). There is a wide scope of back yard poultry keeping in view the geographical situation and participation of women in animal agricultural production system. There is urgent need to establish a regular and reliable market network for disposable animal products at better prices. For economic optimization rather than biological maximization, new technologies need to develop along with improvement in existing ones through integration of livestock with crop production. In fact, crop production and livestock rearing go side by side and are mutually supplementary and complementary to each other. While farmyard manure is an important source of nutrient supply to crops and orchards, the byproducts from crops and trees are used as fodder. To meet the fodder requirements of livestock, companion cropping of fodder crops and trees is also practiced under silvi–pastoral systems in the area. The most common sorghum, cluster bean and *Subabool* + oats are used as a fodder for animals.

AGROFORESTRY

Agroforestry is a collective name for land use system in which woody perennials (trees, shrubs etc.) are grown in association with herbaceous plants (crops, pastures) or livestock in spatial arrangement. In general, there are 4 basic components of agroforestry such as Agri–silviculture system (trees + crops), Agri–horticulture system (fruit trees + crops), Silvipastoral system (trees + pasture or animals), and Agri–silvipastrol system (trees + crops + pasture or animals). There are plenty proofs to illustrate that on the whole productivity, soil fertility improvement, soil conservation, nutrient cycling, micro climate improvement, carbon sequestration potential of an agroforestry system is much more than an annual system. For example, sugarcane+ *poplar* combination gave the higher returns than any other crop in first three years (Dhyani *et al*., 2009a) and then poplar intercropping with wheat-*kharif* fodder for successive years. Similarly, the net income obtained from *poplar* with aromatic crops was higher than growing of sole poplar or sole crop (Chauhan, 2000). Weed infestation could be greatly reduced under suitable agroforestry system (Dhyani *et al*., 2009b). Samra *et al*., 2000 reported increased the soil organic carbon content (0.39 to 0.52%) and available nutrients under the *Acacia nilotica* + *Saccharum munja* after five years. Agroforestry system also helps in moisture conservation and nutrients cycling. Alley cropping with leguminous trees *viz*., Subabul (*Leucaena leucocephala*) was effective for erosion control on sloppy lands (Dhyani *et al*., 2003). The advantage of alleys of shrubs or trees for control erosion is obvious but obtained at the price of slightly lower yields from the annual crops but alley cropping with trees and shrubs are the important sources of organic nutrient (Solaimalai *et al*., 2005). Trees crowns protect the soil from the impact of rain drops and create a specific micro-climate in particular area and increased the agricultural production due to windbreaks and shelterbelts (Rao and Sita Ram, 1980). Plantation of *Khejri* trees for various uses on on–farm is common practices in Rajasthan. Higher biomass production under Khejri tree canopy is due to high fertility status. These systems also act as a refuse to biodiversity after catastrophic event such as fire (Griffith, 2000). In coastal areas, *Casuarina equisetifolia* and other trees are grown in association with crops on farm lands for cash and generate small timber. Agroforestry system are promising land use system to increase and conserve aboveground and soil C stocks to mitigate climate change.

CONCLUSION

In recent years, decline in crop yield, farm profit and rising costs of agricultural inputs in current production system are posing a threat to food security and livelihood of farmers particularly in developing countries. Sustainability of any production system is the only way for balanced economic growth and rational utilization of natural resources without and causing environmental health. Hence, diversified agriculture is an alternate food production system that can achieve high yields and farm profits with integration

of several crops, animals and other off/on farm inputs. Diversification practices also consistently promote yield stability in response to aberrant weather conditions particularly in high rainfall or droughts due to having different agricultural enterprises/inputs. Moreover, the diversified system helps small and marginal farmers, who have very small land holding for crop production and a few heads of livestock to diversify farm production, increase cash income, improve quality and quantity of food produced and exploitation of unutilized resources.

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