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Crop diversification with oilseed crops for-maximizing productivity, profitability and resource conservation

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ABSTRACT

Crop diversification is intended to give a wider choice in the production of a variety of crops in a given area so as to expand production related activities on various crops and also to lessen risk. The crop shift (diversification) also takes place due to governmental policies and thrust on some crops over a stipulated time, e.g. establishment of the Technology Mission on Oilseeds to give thrust on oilseeds production as a national need for the country's requirement for less dependency on imports. Crop diversification and also the growing of large number of crops are practiced in rainfed lands to reduce the risk factor of crop failures due to drought or fewer rains. Market infrastructure development and certain other price related supports also induce crop shift. Inclusion of trees in the farming system results in moisture and nutrient conservation in semi-arid tropics. The article attempts a critical review on crop diversification in rainfed regions of the country and also discusses several facets of crop diversification that include; diversification of rice-wheat system with oilseeds; diversification of oilseeds through intercropping, promising crop sequences involving oilseeds in different states. Potential areas are suggested for various oilseed crops in different parts of the country. Further, the role of trees as a component of crop diversification for maximizing productivity, profitability leading to resource conservation is highlighted.

Key words: Diversification, Oilseeds, Profitability, Resource conservation

In the changing agricultural scenario during globalization, agriculture in India has to face new challenges to compete at the global level in many agricultural commodities. Indian agriculture is now facing second generation problems like rising or lowering of water-table, nutrient imbalance, soil degradation, salinity, resurgence of pests and diseases, environmental pollution and decline in farm profit. Crop diversification shows lot of promise in alleviating these problems through fulfilling the basic needs and regulating farm income, withstanding weather aberrations, controlling price fluctuation, ensuring balanced food supply, conserving natural resources, reducing the chemical fertilizer and pesticide loads, environmental safety and creating employment opportunity (Gill and Ahlawat, 2006). Diversification is gradually taking place as a consequence of either launching macro-economic reforms in agriculture sector or rising domestic demand due to urbanization and increasing income levels. Crop diversification has been recognized as an effective strategy for achieving the objectives of food security, nutrition security, income growth, poverty alleviation, employment generation, judicious use of land and water resources, sustainable agricultural development and environmental improvement (Hegde *et al.,* 2003). The ability of the country to diversify the cropping pattern for attaining various goals depends on the opportunities available for diversification, the need for diversification and responsiveness of the farmers to these needs and opportunities.

CROP DIVERSIFICATION

The opportunities for crop diversification emerge from technological breakthroughs, changes in demand pattern, development of irrigation, availability of marketing infrastructure and new trade arrangements. The necessity for crop diversification arise on account of the need for (i) reducing risks associated with yield, market and prices (ii) arresting the degradation of natural resources and the environment and (iii) attaining national goals like employment generation, self-reliance in critical crop products and for earning foreign exchange. Diversification is the process to take advantage of emerging opportunities created by technology, new markets, changes in policy etc. to meet certain goals, challenges and threats and to reduce risk (Chand and Chauhan, 2002). Crop diversification is one of the major components of diversification in agriculture. Crop diversification may be adopted as a strategy for profit maximization through reaping the gains of complementary and supplementary relationships or in equating substitution and price ratios for competitive products. It also acts as a powerful tool in minimization of risk in farming.

These considerations make a strong case for farm/crop diversification in India. (Gupta and Tewari, 1985).Crop diversification in India is generally viewed as a shift from traditionally grown less remunerative crops to more remunerative crops. Market infrastructure development and certain other price related supports also induce crop shift. Higher profitability and also the resilience/stability in production also induce crop diversification. Crop diversification and large number of crops are practised in rainfed areas to reduce the risk factor of crop failures due to drought. Crop substitution and shift are also taking place in the areas with distinct soil problems for example, the growing of rice in high water-table areas replacing pulses and cotton, promotion of soybean in place of sorghum in vertisols (medium and deep black soils). The crop diversification also takes place due to government policies and thrust in some crops over a given time, eg. establishment of Technology Mission on Oilseeds (TMO) to give thrust on oilseed production as a national need for country's requirement to reduce imports (Hazra, 2001).

Benefits of crop diversification

The crop diversification may result in enhanced profitability, reduce pests, spread out of labour more uniformly, different planting and harvesting times can reduce risks from weather and new crops can be renewable resources of high value products.

Crop diversification in rainfed regions aims to make rainfed agriculture achieving nutritional security, more employment and income generating, eco-friendly, poverty alleviation and comparative advantage in new trade regime (Vittal *et al.,* 2007). Some of the issues and functions provided by diversification in rainfed regions are mentioned in Table 1.

Perennial species play an important role in areas where cropping of annual plants has reduced total water use and allowed water-table to raise, with a resultant salinization. In such areas, an appropriate density of trees in agroforestry systems can help reestablish a hydrological balance that keeps the water-table and its salt content below the root zone of the crops. The emphasis in agro-ecological analysis is on the processes and balance of resource supply and capture and on the competitive and complimentary relationships between the planned and unplanned biodiversity (Table 2).

Crop diversification in rainfed regions of India

Land degradation and climate change are the twin problems challenging rainfed agriculture in India. Kinds, degree and extent of land degradation are of immediate concern in sustaining production system, reducing cost of production and natural resource management and conservation.

The crops are grouped into rice, oilseeds, pulses and coarse cereals. In each production system based upon diversification index and severity of soil degradation, horizontal and vertical diversification is suggested. Horizontal diversification is advantageous in effective utilization for natural resources, *viz*. soil, light water and conservation, employment generation and risk minimization. Vertical diversification aims at reducing the soil loss, high biomass production, high income and employment generation through year round activity and addition of organic matter to soil, organic linkage between agriculture and

Table 1. Issues and functions provided by diversification in rainfed regions

Issues	Functions provided by diversification in rainfed regions
Productivity and stability	Increased yield, reduce intra-seasonal variation and improved stability through diverse components, *viz*. crop, tree, plant and animal
High risk and high cost	Risk and cost minimization through yield and income from annual and perennial mixtures
Unabated land degradation	Minimization of kinds, effect and extent of land degradation by appropriate land care through alternate land use systems
Inadequate employment	Staggered employment round the year
Low profitability	High income generation from various Components
Poor energy management	Energy efficient implements

Table 2. Some factors affecting decisions of Agroforestry in crop diversification in dryland regions of India

Short term profit factors	Crop production and quality, forage production level, quality and timing, yields of trees, economic shrubs and forages, input costs, output prices for annuals, perennials and livestock products
Dynamic factors	Short term to medium term: Soil health, tree and forage density, abiotic stresses, water harvesting, optimum tillage
Sustainable factors	Soil degradation, nutrient loss, tree/forage establishment, risk factors. yield variability, price variability, flexibility of the enterprise in response to changed conditions, the farmers attitude to risk.
Whole -farm factors	Total arable area, machinery, total feed requirements, financial support, labour availability, quality and cost the farmer's objectives (profit, risk reduction, sustainability), traditional wisdom.

industry wherein the scope is widened for post-harvest value addition by practising the enterprises like agroforestry (alley cropping, silviculture, silvipasture, agri-horticulture and agri-silvi-pastoral system), sericulture, rainfed horticulture, olericulture, medicinal aromatic plants, other economic shrubs like dye yielding plants and most importantly animal component for dairy, poultry, apiary, rabbit rearing etc. These complementary enterprises with multiple objectives and advantages in rainfed regions may help for comparative advantage in the present trade regime. The details of crop diversification in oilseeds based production system of Andhra Pradesh for two situations are described below :

1.0 Crop Diversification index 80-100% (Nalgonda)

Soils: Deep loamy, clayey mixed red and black soils. Soil degradation status: Water erosion, high severity with moderate loss of top soil. Rainfall: 763 mm and Length of growing period: 120-150 days.

Suggested Diversification

Horizontal Diversification

Castor + Pigeonpea/Setaria/Cowpea + Sorghum + Mungbean/Urdbean

Intercropping one row of clusterbean between 90 cm castor rows.

Urdbean + Castor (6:1)

Vertical Diversification

Parkland systems: *Azadirachta indica, Acacia nilotica, Tamarindus indica*

Trees on bunds: *Tectona grandis, Leucaena leucocephala, Borassus flabellifera, Cocos nucifera, Acacia nilotica var, cupressiformis*

Silvipastoral system: *Leucaena leucocephala + Stylosanthes hamata, Leucaena leucocephala + Cenchurs + ciliaris*

Alley cropping: *Leucaena leucocephala + Sorghum/ Pearlmillet, Gliricidia sepium + Sorghum/Pearlmillet*

Agri-horti system: Mango + short duration pulses.

Fruit: Mango, Ber, Custard apple, guava, Pomegranate, Aon

Fodder/green biomass: *Leucaena leucocephala. Azadirachta indica, Albizzia lebbeck, Bauhinia purpurea, A.procera, B.monosperma, A.amara, D.sissoo*

Medicinal and Aromatic Plants: *Catharanthus roseus, Cassia angustifolia, Aloe barbadensis, Withia somnifera, Cymbopogan martini, Cymbopogan flexuosus, Vetiveria zyzanoides and Palma rosa.*

2.0 Crop Diversification index 60-80%

Cuddapah

Rainfall: 605 mm and Length of growing period: 80-120 days

Soils: Deep loamy, clayey mixed red and black soils. Soil degradation status: Water erosion, high severity with moderate loss of top soil (Kurnool)

Soils: Deep loamy, clayey mixed red and black soils

Rainfall: 748 mm and Length of growing period: 80-120 days (Anantapur)

Soils: Deep loamy, clayey mixed red and black soils. Rainfall: 497 mm and Length of growing period: 60-90 days

Suggested diversification

Horizontal diversification

Monocropping of groundnut : can be taken up in 50% of the *kharif* cultivation area.

Groundnut+ Pigeonpea (7:1)

Groundnut + Castor (7:1 or 11:1)

Groundnut + Pigeonpea (11:1)

Groundnut + Pearlmilleet (6:2)

Vertical diversification

Crop + livestock (sheep @ Rs10/ha) system of farming will give 80% more income than crop system alone.

Fodder/green biomass: *Dalbergia sissoo, Glyricidia, Albizzia lebbeck, Cassia siamea, Azadirachta indica/stylo, Marvel - 8 grass*

Fruit: *Ber, custard apple, pomegranate, aonla + kharif* spreading crops

Medicinal and Aromatic plants: *Cassia angustifolia Catharanthus roseus*, Palma rosa, *Vettiveria zyzanoides*, Rose, Geranium

Vegetables: Onion, brinjal, chillies, cowpea, cucumber, clusterbean, drumstick.

India is amongst the largest vegetable oil economies in the world next only to USA, China and Brazil. In the agricultural economy of India, oilseeds are important next only to food grains in area, production and value. The diverse agro-ecological conditions in the country are favourable for growing nine oilseeds which include seven edible oilseeds (groundnut, rapeseed-mustard, soybean, sunflower, sesame, safflower and niger) and two non - edible oil seeds (castor and linseed). Oilseed crops have potential for increasing cropping intensity and profitability in wide ranging cropping systems. Oilseed crops by nature are hardy, mostly grown under rainfed conditions and impart stability of production system under harsh conditions. Oilseeds will have an edge over other crops in price, wider adoptability and relative optimal production under environmental stress conditions.

Introduction of high-yielding varieties in oilseed crops replaced a number of traditional low yielding crops because of their higher efficiency in the utilization of rainfall and moisture, resulting in higher yield and returns. Safflower has comparative economic advantage over other popular crops like rainfed wheat, coriander, chickpea etc.

The crop is distinctly remunerative under conditions of limiting moisture in several traditional as well as non-traditional areas viz black soil areas of Karnataka, Maharashtra, Andhra Pradesh and Rajasthan. Sunflower, by virtue of its photo-insensitivity and wide adaptability to soil types, has a greater role to play in contingency cropping plans. It is suitable for late planting in *kharif* in delayed rains. It can also be planted whenever the kharif planted crop fails due to lack of rains. Sesame has great potential as summer crop under limited irrigation in Telangana region of Andhra Pradesh. Good yields of soybean have been obtained from the crop grown in post-rainy season (rabi/kharif) in many states (Hegde, 2006).

Diversification of rice-wheat system with oilseeds: Punjab and Haryana have become major rice and wheat producing states from the last three decades with the dominant rice-wheat cropping system. To reduce the fatigue of this rice-wheat system, alternate crops like oilseeds can be grown without hampering the profitability of the system. At least 0.5-0.6 m.ha of rice area in Punjab could be shifted to soybean in comparatively upland and less irrigated area. The area which goes to late wheat due to delayed harvest of basmati rice can be shifted to sunflower cropping. Coarse rice-potato-sunflower recorded higher returns (Rs 70,262/ha) compared to coarse rice-wheat system (Rs 35,881/ha). In Haryana, the basmati rice area invariably goes for late sown wheat. It is suggested that the basmati area may be put to sunflower cropping in place of wheat. Soybean and pulses like pigeonpea should be promoted by diverting some of the rice area. In Uttar Pradesh, where rice-wheat system is important, it is possible to shift part of rice area to soybean and early pigeonpea. Rabi sunflower could also be promoted in place of wheat.

Diversification of oilseeds in upland rice/rice fallow situation: Wherever water resources are limiting such as tail end area of irrigation command, tank fed area and well irrigated areas, oilseed crops like groundnut, soybean, sunflower, sesame etc. can be profitably cultivated. In rice fallow situations of Cauvery delta (Tamil Nadu) and coastal Andhra Pradesh, soybean and sesame can be profitably grown. In Tungabhadra project areas of Karnataka and Andhra Pradesh, Sriramsagar project area of Andhra Pradesh and Jayakwadi project area of Maharashtra, it is profitable to grow groundnut, sunflower and sesame under rice fallow situations. Groundnut has great potential under residual moisture after the harvest of *kharif* rice in coastal region of Karnataka and Andhra Pradesh. There is great potential of *rabi*/summer groundnut in rice fallows and on residual moisture in flood plains in Assam, West Bengal, Orissa and Chhatisgarh. Mustard has an excellent potential in rice fallows in North-eastern states. As a summer crop in eastern states, sesame is profitably grown after rice. In the upland areas of Orissa, Tamil Nadu, Bihar and Andhra Pradesh, groundnut (*kharif*), soybean and sunflower are more remunerative as compared to upland rice (Reddy and Suresh, 2008).

Diversification with oilseeds in nontraditional areas and crop substitution

Oilseed crops by virtue of low irrigation requirement and better remunerative price are ideally suited to replace low yielding other crops and become popular even in non-traditional area (Palaniappan and Jeyabal, 2002).

The diversification of traditional crop base with annual oilseed crops is given in Table 3.

Diversification of oilseeds through intercropping

Groundnut

(a) Inter-cropping with short duration annuals

Groundnut, a long duration crop can be grown along with sunflower so that early season rains benefit sunflower and late rains benefit groundnut, thereby giving some assurance to the dry land farmers. Advancing sowing of groundnut by 15-30 days prior to sunflower reduces the competition due to shading of sunflower. Research data indicated that a net return of Rs 10,120 and 12,615/ha could be obtained under sunflower groundnut intercropping system in Saurashtra region of Gujarat and West Bengal, respectively. Intercropping groundnut with sesame was also found profitable in this region; the optimum row ratio is 4:1 with net returns to the tune of Rs 9,947-12,292/ha.

Groundnut with pearl millet and sorghum is common in red soils of the semi-arid tract of India. The optimum row ratio in this intercropping system is 1:1 with Virginia groundnut and 1:2 with Spanish groundnut. Two rows of sorghum with eight rows of groundnut is one of the best combinations providing 38-53% yield advantage over sole crops. The system provides net returns to the tune of Rs 3,000/ha at Hyderabad and Indore. Groundnut is commonly intercropped with maize in Madhya Pradesh and Bihar. In Sundarban area of West Bengal (coastal saline tract) and Dharwad region of Karnataka yield advantage was found quite high when 3 rows of groundnut is alternated with 3 rows of chillies.

(b) Intercropping with long duration annuals

Among the legumes, pigeonpea + groundnut (3:1) was the most prevalent intercropping system in India. At Jalgaon (Maharashtra), this system provided net returns up to Rs 22,338/ha. Raising 2-3 rows of groundnut in between cotton rows spaced 2 m apart is reported to give higher income than raising either of them alone. Castor intercropped with groundnut is better than growing castor

The oilseed crops in diversification are explained here.

Crop	Area suggested for diversification
Groundnut	• As a replacement crop for minor millets in Bihar and Orissa • As an irrigated crop in Kosi command and in Tawa command in Bihar and Madhya Pradesh • Substitute rice-groundnut with rice-rice system to prevent build up of pests and diseases.
Soybean	• As a replacement crop for minor millets in Bihar and Orissa • As a rotational crop in pest endemic areas of rainfed cotton. • In nontraditional areas of North-eastern hills under agripastoral or agri-silvicultural system • Diverting some *kharif* cereal area to soybean in situations of water scarcity and to restore soil-health in north India.
Rapeseed-mustard	• As a replacement crop for low yielding rainfed wheat • In *diara* tract in northern and eastern India and Gujarat
Sunflower	• As a replacement crop for desi wheat, cotton, chickpea, sorghum in black cotton soils in peninsular India. • As a spring crop in northern India.
Sesame	• As a summer crop in central peninsular and eastern India where only limited irrigation is available.
Castor	• As a replacement of cotton in some regions of western Haryana and Rajasthan • As bund crop in all regions.

Table 3. Diversification of traditional crop base with annual oilseed crops

Prevailing crop	Suggested crop	Region
Rice fallow	Soybean and sesame	Cauvery deltaic areas of Tamil Nadu and coastal Andhra Pradesh
Upland rice	Groundnut (*kharif*), soybean and sunflower	Upland rice areas of Orissa, Tamil Nadu, Bihar and Andhra Pradesh
Cotton	Safflower and sunflower	Karnataka and adjoining areas of Andhra Pradesh
Chickpea, dryland wheat and Coriander	Safflower (sole crop)	Andhra Pradesh (*rabi*), Karnataka, Maharashtra, Part of Madhya Pradesh (Malwa region)
Linseed and Barley	Safflower (sole crop)	South eastern Rajasthan (Udaipur)
Rice fallow	Groundnut, sunflower and sesame	Most part of rice growing areas

alone. This system provided net returns of about Rs 10,000/ha at Junagadh and at Kanpur.

(c) Intercropping with perennial/plantation crops at early stages

Intercropping groundnut under cassava could give yield advantage of 33 to 55%. In Trivandrum and Orissa 12 q/ha of groundnut, in addition to full yield of tapioca was obtained. Growing groundnut between wide spaced rows of banana is common practice in Tamil Nadu, Maharashtra and parts of Karnataka. Groundnut under coconut plantation is common in Kerala.

Soybean

Soybean when introduced as intercrop exerts less competition to companion crop, it does not impose any allelopathic effects on companion crop and it helps in fertilizer economy. Some of the prominent intercropping systems found suitable are: soybean+pigeonpea, soybean + fingermillet, soybean + sugarcane, soybean + sorghum, soybean + groundnut, soybean in coconut/ mango/guava orchards in various soybean growing areas of the country. Soybean offers much scope for intercropping in sugarcane. By growing soybean as intercrop in sugarcane, the N fertilizer requirement could be cut down to some extent (Kailasam, 1988).

Rapeseed-mustard

Diversification is possible by growing mustard as an intercrop with autumn planted sugarcane, potato, wheat, lentil and chickpea in northern India.

Sunflower

Sunflower + soybean in Marathwada and Vidarbha region of Maharashtra, sunflower + urdbean in Uttar Pradesh are found to be efficient for increasing productivity and monetary returns. Additional net returns expected from different intercropping systems are: Groundnut +

sunflower (Rs 2100 to 9200/ha); Pigeonpea + sunflower (Rs 3500 to 5200/ha) and Soybean + sunflower (Rs 4000 to 10000/ha) in peninsular India. Sunflower + aswagandha (1:6) were found to be highly profitable and merits for diversification in north Karnataka over sole sunflower (Table 4) under rainfed conditions (Chandranath, 2006).

Castor

Castor is usually raised either as a sole crop or intercrop with grain/legumes (pigeonpea, groundnut, mungbean, urdbean and cowpea) and sometimes with horticultural crops like chillies, turmeric, ginger, *Dolichos* and cucumber. The followings are some of the remunerative viable intercropping systems recommended for Southern states of the country. The additional net returns from castor + pigeonpea (4:1) ranges from Rs 3,700 to 12,400/ha, from castor + groundnut (1:3) between Rs 4,200 and Rs 23,700/ha, from castor+urdbean Rs.1,000 to Rs.2,400/ha, from castor + clusterbean (1:2) Rs 4,000 to Rs 6,000/ha, castor + mungbean (1:2) Rs.10,000 to Rs.12,000/ha.

Studies conducted at Hyderabad revealed that the seed yield of sunflower and castor did not differ significantly in all alley widths (3m × 3m, 4.2 × 3m and 5.4 × 3m) when grown with *Faidherbia albida* in comparision with seed yields of respective sole crops (Bheemaiah *et al.*, 1994).

Safflower

Intercropping of safflower with other rainfed *rabi* crops increases the net returns compared to that of sole cropping. An additional net returns of Rs 2,500 to 4,500/ha could be expected in chickpea + safflower and coriander + safflower depending on row ratio of system and status of soil moisture in Karnataka and Andhra Pradesh. In linseed + safflower and mustard + safflower intercropping system, an additional net returns of Rs 3,500 to 5,000/ha could be realized. Intercropping of safflower in wheat increases the net returns by Rs 1,000 to 1,500/ha over sole of wheat.

Sesame

It can be raised as an intercrop with groundnut grown at wider spacing in Gujarat, with finger millet, groundnut in Andhra Pradesh, Karnataka and Madhya Pradesh.

Linseed

Linseed can be grown as intercrop with wheat, chickpea, lentil, coriander and safflower in major crop growing areas.

Diversification with oilseeds in crop sequences

Oilseeds being high value crops have been given priority for inclusion in the cropping systems mainly in cereal and legume-based crop sequence. The level of fertilizer and water supply required for high-yielding varieties of rapeseed-mustard, groundnut, sesame, sunflower, and soybean can give highest output/unit area and enhanced farm income have been identified for different agro-eco regions.

(a) Need based cropping systems for different agro-climatic conditions

In arid ecosystem, the oilseeds mostly grown after cereal whereas in semi-arid, cereal-oilseed, legume-oilseed, oilseed-cereal, and oilseed-legume are prevalent. The details of sequence having oilseed as a component crop clearly indicates the scope for enhancing the production of various oilseed crops in different states/unit of area. Use of quality seed and fertilizer for oilseeds as well as

Table 4. Seed yield (t/ha) and economics (x10^3 Rs/ha) as influenced by row proportions and seed rates of Ashwagandha in companion cropping of sunflower (Raichur)

Treatments	Seed yield	Seed filling %	Gross returns	Net returns	Benefit: Cost ratio
Cropping System					
Sole sunflower	1.33	77.5	21.31	11.56	1.85
Intercropped sunflower	1.22	70.5	41.25	28.99	3.28
CD (P=0.05)	NS	NS	3.93	3.68	0.34
Row proportions (R)					
1:3	1.13	64.8	37.04	24.37	2.92
1:4	1.18	67.2	38.19	27.08	3.06
1:5	1.27	72.5	43.24	30.55	3.47
1:6	1.27	74.8	44.16	31.20	3.46
1:7	1.25	73.9	44.44	31.76	3.49
CD (P=0.05)	0.097	4.6	2.56	2.47	0.22
Seed rate of Ashwagandha (S)					
50 %	1.20	72.0	40.42	27.66	3.17
100 %	1.24	69.0	42.41	30.35	3.39
CD (P=0.05)	NS	NS	1.62	1.56	0.14

other crops in the sequence enhanced the total production of the system. For instance, the sunflower productivity in arid and semi-arid ecosystems were realized 1.14, 1.18, 1.30, and 1.40 t/ha in various sequences as against the national average productivity of 0.66 t/ha during 1996-97. Similarly the groundnut and soybean yield in cotton-groundnut and rice-soybean sequence was 3.45 t/ha and 2.45 t/ha respectively compared to country's average productivity of 1.15 and 1.0 t/ha in semi-arid ecosystem. The rapeseed-mustard productivity in coastal ecosystem was marked (1.41 t/ha) in rice-mustard-brinjal cropping system. This rate of growth was measured 38.9% higher than average productivity of the nation.

(b) Promising crop sequences involving oilseeds in different states

Directorate for Cropping System Research has identified promising crop sequences for different states wherein oilseed is one of the component crops either as *kharif* or *rabi* in the systems (Yadav and Shukla, 2002). In Ranchi, (Bihar), rice-linseed is promising crop sequence under limited water supply situations, In Mandi (Himachal Pradesh), inclusion of toria between rice-potato and maize-potato, increased the total farm income to the tune of Rs 41,950/ha and Rs 40,744/ha respectively by enhancing the system productivity. In Ujjain district of Madhya Pradesh and in Manipur, blackgram-mustard, soybean-wheat, and soybean-gram were found promising crop sequence having oilseeds as one of the component crop. In Maharashtra, soybean was observed prominent oilseed crop associated with cereal, legume and other oil crops in the sequence. The income realized was Rs 20,460, 27,276, and Rs 33,099/ha from soybean-gram, sesame-sunflower-groundnut and sorghum-sunflower-groundnut in the region. Growing of mustard and linseed after rice, urd and maize was a common practice in eastern Uttar Pradesh. Soybean-wheat recorded almost similar net returns as that of rice-wheat system in Punjab with high B: C ratio of 2.61 as against 2.41 in rice-wheat system.

(c) Maximizing productivity and resource use from oilseed crops

The oilseed crops offer excellent opportunity for maximizing productivity under limited moisture availability. Sunflower crop productivity can be increased by more than 60% with limited irrigation at critical stages (Table 5).

Safflower yields can be doubled by providing two irrigations in Malwa plateau. In Western zone of Uttar Pradesh, rising of rice-mustard-mungbean for 1 year followed by rice-wheat-mungbean in succeeding 2 years registered in saving of water to the tune of 10.5% clearly favouring for the diversification of the rice-wheat system.

Table 5. Seed yield (kg/ha) of sunflower as influenced by irrigation at different stages

Irrigation at specific growth stage	Akola	Digraj	Mean	% increase
Control (No irrigation)	438	1159	799	-
Seedling stage (2)	621	1524	1073	34
Bud initiation stage (3)	588	1598	1093	37
Flowering stage (4)	613	1420	1017	27
Seed development stage (5)	525	1329	927	16
Two irrigations*	703	1649	1176	47
Three irrigations*	804	1871	1338	67
Four irrigations**	941	2070	1506	88

*at any of stages from 2-5; ** at all stages from 2-5

In Bihar, rice-potato-sunflower system recorded higher rice equivalent yield, net returns, B: C ratio, land use efficiency, production efficiency than traditional rice-wheat-green manuring (Table 6). At Jalandhar (Punjab), rice-potato-sunflower registered higher rice equivalent yield, economic efficiency, land use efficiency, irrigation water productivity and nutrient productivity compared to rice-wheat system.

The hybrids available in sunflower, castor and safflower have shown the productivity improvement to the magnitude of 28.6 %, 18.2 %, and 11% respectively over varieties under moisture and nutrient stress situations in the respective major crop growing areas (Table 7).

Mustard in inter-cropping with potato, sunflower after potato have been found efficient in utilizing the fertilizer applied to potato. The fertilizer can be economized with soybean under intercropping system. In Telangana region of Andhra Pradesh, fertilizing sunflower at 50% recommended dose with *kharif* groundnut as a sequence crop has given sunflower yields comparable at 150% recommended dose of sunflower-sunflower sequence. Hence, when legume like groundnut precedes sunflower; the fertilizer requirement for succeeding sunflower needs suitable modification. By adopting integrated nutrient package, about 33% higher yield (116 kg/ha) could be obtained in summer sesame (Palaniappan *et al.*, 1999).

Role of tree species in nutrient conservation

Trees can increase nutrient inputs to agroforestry systems by retrieval from lower soil horizons and weathering rock. Agroforestry systems involving-nitrogen fixing tree species help in building soil fertility through leaf litter fall, fixation of atmospheric nitrogen and recycling of nutrients from lower soil layer to surface soil (Young, 1990). The beneficial association of nitrogen-fixing trees with sorghum (Suresh and Rao, 1999) and cowpea (Suresh and Rao, 2000) in semi-arid tropics are well documented.

Table 6. Effect of rice based cropping systems on yield (t/ha) and resource use efficiency

Crop sequence	Rice equivalent yield (t/ha)	Net income (Rs/ha)	Benefit : Cost ratio	Land use efficiency (%)	Production efficiency	Energy output: (kg/ha/day) input ratio
Rice-wheat-GM	11.54	29,242	0.99	64.1	49.3	3.32
Rice-potato-sunflower	23.92	61,553	1.31	81.4	80.6	3.21
Rice-mustard-sunflower	12.72	34,066	1.21	86.6	40.3	3.49

Table 7. Seed yield (kg/ha) and economics of oilseeds under nutrients and moisture stress

Crop	Centre	Recommended MC+FA	Farmer's method (FM)	Increase over FM %	Additional net returns (Rs/ha)
Groundnut	Junagadh	2,194	2,035	8.0	1,710
Soybean	Indore	2,242	1,765	27.0	4,014
Sunflower	Raichur	974	773	26.0	4,165
Castor	Mahaboobnagar	926	741	24.9	1,057
		Potential cultivar	*Check cultivar*	*increase over check %*	
Groundnut	Junagadh	2,195	1,944	12.3	5,615
Soybean	Indore	2,149	2,048	5.0	1,368
Sunflower	Raichur	998	761	31.1	3,685
Castor	Mahaboobnagar	889	752	18.2	1,207

Mean of 2 years (2001-02 to 2002-03); MC : Moisture conservation and FA : Fertilizer application

Increasing nutrient use efficiency

Increasing the nutrient use efficiency through agroforestry can be achieved by

(i) Increasing the cycling of nutrients from tree litter and pruning via the soil into the crops; (ii) Reducing losses by leaching and (iii) Reducing the losses by erosion.

The nutrient transfer from tree residues to crops is through litter and prunings. Perennial-crop combinations can provide 6-20 t/ha/year of leaves and small branches and hedgerows typically provide 5-12 t. The annual hedgerow biomass can be as low as 2 t in SAT and rise to 20 t in humid areas. Planted fallows can produce 12-30 t/ha/year during the tree fallow period. The nutrient content from NFTs is typically N 2.5-4%, P 0.1-0.3%, K 1.0-2.5% and Ca 1.5-2.0%. Prunings have the advantage over natural litter in that the leafy matter is transferred before loss of nutrients by senescence. The magnitude of addition through 5t tree residues would be N 120-200, P 5-15, K 50-100 and Ca 70-100 kg/ha/year. To these should be added substantial quantities in the decay of fine roots (which contain 50% or more of leaf N). The nutrients in a maize crop with a grain yield of 3 t/ha are N 120-150, P 20-25, K 80-100 and Ca 20-30 kg/year. So, except for P, the tree residues can meet the nutrient requirements of associated crop. In SAT, N supply through Leucaena prunings was 35-74 kg/ha/year (Korwar, 1992). The available N at sowing was higher by 49 and 19 kg respectively in plots where prunings returned and not returned than sole sorghum. A saving of 9.5, 9.4 and 4.3 kg N to groundnut crop was observed when prunings of *Dalbergia, Leucaena* and *Albizia* were returned (Srinivasa Rao and Bhemaiah, 2001). The organic carbon, P and K were higher (1.02%, 32 kg and 180 kg/ha) in plots with F.albida trees (@ 625 trees/ha) than no tree control (0.69%, 16 kg and 162 kg/ha) in SAT (Korwar and Pratibha, 1999).

India being a vast country of continental dimensions presents wide variations in agro-climatic conditions. Such variations have led to the evolution of regional niches for various crops. Historically, regions were often associated with the crops in which they specialize for various agronomic, climatic, hydro-geological, and even, historical reasons. In new challenges and new changes including the achievement of food self-sufficiency, the area shift that tended towards cereals in the immediate aftermath of the green revolution, has started moving in the opposite direction *i.e.* from cereals to non-cereals like oilseeds and pulses. This review has clearly brought out the advantages of crop diversification with oilseeds in marginal eco-systems to make the cropping enterprise as a profitable venture avoiding risks. Hence, crop diversification with oilseeds could be used as a tool for maximizing productivity, profitability leading to resource conservation. The further thrust areas of research included :

- In the present scenario of resource conservation followed in the Indo-Gangetic plains where cereal-based cropping system is predominant; the potentiality of leguminous oilseed like soybean may be exploited.

- The development of cost effective or high yield-low cost technology can change the scenario for oilseeds production in the country.
- Evaluation of cultivars of various oilseeds crops to suit to the requirement of non-traditional areas and seasons.
- Efforts should be diverted to develop the potential oilseeds growing areas based on the agro-eco region basis and involving oilseeds of tree origin.
- Both technological and price factors are important variables influencing supply response of edible oilseeds.

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