Crop Diversification with Oilseed Crops for Maximizing Productivity, Profitability and Resource Conservation

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In the changing agricultural scenario in the world as a result of 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. 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. 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. 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 practiced 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, for example creation of Technology Mission on Oilseeds (TMO) to give thrust on oilseed production as a national need for country's requirement to reduce imports.

Benefits of Crop Diversification:

The crop diversification may results in the following anticipated benefits.

(i) Alternative crops may enhance profitability

(ii) Diversified rotations can reduce pests

(iii) Labour may be spread out more uniformly

(iv) Different planting and harvesting times can reduce risks from weather

(v) 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 given below in table-1.

Table-1. Issues and Functions provided by diversification in rainfed regions

Issue	**Functions provided by diversification**
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

Perennial species play an important role in areas where cropping of annual plants has reduced total water use and allowed water table to rise, with resultant a salinization. In such areas, an appropriate density of trees in agro-forestry 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).

Table-2. Some factors affecting decisions on in crop rotation 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.

Suggested 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 are 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 industry wherein the scope is widened for post harvest value addition by practicing the enterprises like agro forestry (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 follows:

1.0 Crop Diversification index 80-100%

1.1. Crop based production system: Oilseeds

1.1.1. Soil degradation Status: Water erosion, high severity with moderate loss of top soil

State: Andhra Pradesh District: Nalgonda
Soils: Deep loamy, clayey mixed red and black soils
Rainfall: 763 mm Length of growing period: 120-150 days

Suggested Diversification

Horizontal Diversification

Castor + pigeon pea
Castor + Sorghum
Castor + mungbean / Urdbean
Castor + Pigeon pea (2:1)
Intercropping one row of clusterbean between 90 cm castor rows.
Urdbean + castor (6:1), Castor + Setaria and
Castor + Cowpea

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, Amla
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, Al Psoralea, Palma rosa.*

2.0 Crop Diversification index 60-80%

2.1. Crop based Production system: Oilseeds

2.2.1. Soil Degradation Status: Water erosion, high severity with moderate loss of top soil

State: Andhra Pradesh District: Kurnool
Soils: Deep loamy, clayey mixed red and black soils
Rainfall: 605 mm Length of growing period: 80-120 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 @ 10/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, amla + 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.

3.0 Crop Diversification index 40-60%

3.1. Crop based Production system: Oilseeds

3.2.1. Land Degradation Status: Water erosion, high severity with moderate loss of top soil.

State: Andhra Pradesh District: Cuddapah
Soils: Deep loamy, clayey mixed red and black soils
Rainfall: 748 mm Length of growing period: 80-120 days

Suggested Diversification

Horizontal Diversification
Monocropping of groundnut: In 50% of the area
Groundnut + pigeonpea (7:1)
Groundnut + castor (7:1 or 11:1)
Groundnut + Pigeon pea (11.1)
Groundnut + pearl milleet (6:2)

Vertical Diversification
Crop + livestock (sheep @ 10/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, amla + *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.

4.0 Crop based production system: Oilseeds

4.1. Soil degradation Status: Water erosion, high severity with moderate loss of top soil.

State: Andhra Pradesh District: Anantapur
Soils: Deep loamy, clayey mixed red and black soils
Rainfall: 497 mm Length of growing period: 60-90 days

Suggested Diversification

Horizontal Diversification
Monocropping of groundnut: In 50% of the area
Groundnut + pigeon pea (7:1)
Groundnut + castor (7:1 or 11:1)
Groundnut + Pigeon pea (11.1)
Groundnut + pearlmilleet (6:2)

Vertical Diversification
Crop + livestock (sheep @ 10/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, amla + *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 terms of area, production and value. The diverse agro ecological conditions in the country are favourable for growing nine oilseeds which include seven edible oilseeds *viz* groundnut, rapeseed-mustard, soybean, sunflower, sesame, safflower and niger and two non –edible oil sources *viz* castor and linseed. Oilseed crops have potential for increasing cropping intensity and profitability in wide ranging cropping systems. Oilseed crops by nature are hardy crops mostly grown under rainfed conditions and impart stability of production system under harsh conditions. Oilseeds will have an edge over other crops in terms of 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 in 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 nontraditional areas *viz* black soil areas of Karnataka, Maharashtra, Andhra Pradesh, Rajasthan etc. 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 case of delayed rains. It can also be planted whenever the *kharif* planted crop fails due to failure 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*/summer) in many states.

1) 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 rice-wheat system, alternate crops like oilseeds can be grown without hampering the profitability of the system. At least 5-6 lakh hectares of rice area in Punjab could be shifted to soybean in comparatively upland and less irrigated area (dry area). The area which goes to late season wheat due to late harvest of basmati rice can be shifted to sunflower cropping. Course rice-potato-sunflower recorded higher returns (Rs.70262/ha) compared to course rice-wheat system (Rs.35881/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 pigeon pea should be promoted by diverting some of the rice area. In Uttar Pradesh, where rice-wheat system is important, it is possible to shift the part of rice area to soybean and early pigeon pea. *Rabi* sunflower could also be promoted in place of wheat.

2) 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 deltaic areas of 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.

3) 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 areas (Palaniappan and Jeyabal, 2002). The oilseed crops in diversification are given below.

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 sprig 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.

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

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 A.P.
Cotton	Safflower and sunflower	Karnataka and adjoining areas of A.P.
Chickpea, dryland wheat and Coriander	Safflower (Sole crop)	A.P.(*rabi*), Karnataka, Maharashtra, Part of M.P. (Malwa region)
Linseed and Barley	Safflower (Sole crop)	South eastern Rajasthan (Udaipur)
Rice fallow	Groundnut, sunflower and sesame	Most part of rice growing areas

4) 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 benefits 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 returns of Rs.10,120 and 12,615 per hectare 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.9947-12292 per ha.

Groundnut with pearl millet and sorghum is very 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.3000/ha at Hyderabad and at Indore. Groundnut is very 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) is the most prevalent intercropping system in India. At Jalgaon (Maharashtra), this system provided net returns upto 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 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 33-55%. In Trivendrum 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. Intercropping of summer groundnut in 6 year old teak and sissoo plantations did not prove beneficial (Bheemaiah *et al*.,1999).

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 + finger millet, soybean + sugarcane, soybean + sorghum, soybean + groundnut, soybean in coconut/ mango/guava orchards in various soybean growing areas of the country.,

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 inter cropping 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) is highly profitable and merits for diversification in North Karnataka over sole sunflower (Table 4).

Table-4 Seed yield and economics as influenced by row proportions and seed rates of ashwagandha in companion cropping of sunflower (Raichur)

Treatments	Seed yield (kg/ha)	% seed filling	Gross returns (Rs/ha)	Net returns (Rs/ha)	B:C ratio
Cropping System					
Sole sunflower	1332	77.5	21312	11555	1.85
Intercropped sunflower	1223	70.5	41254	28990	3.28
CD at 5%	NS	NS	3928	3676	0.34
Row proportions(R)					
1:3	1132	64.8	37040	24367	2.92
1:4	1184	67.2	38186	27079	3.06
1:5	1265	72.5	43239	30547	3.47
1:6	1273	74.8	44160	31198	3.46
1:7	1254	73.9	44435	31762	3.49
CD at 5%	97	4.6	2562	2470	0.22
Seed rate of ashwagandha(S)					
50 percent	1202	72.0	40417	27659	3.17
100 percent	1241	69.0	42406	30349	3.39
CD at 5%	NS	NS	1620	1562	0.14
Interaction RxS					
CD at 5%	NS	NS	NS	NS	NS

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 following 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.3700 to 12,400/ha, from castor + groundnut (1:3) between Rs.4200 and Rs.23700/ha, from castor + urdbean Rs.1000 to Rs.2400/ha, from castor + clusterbean (1:2) Rs. 4000 to Rs.6000/ha, castor + mungbean (1:2) Rs. 10000 to Rs. 12000/ha.

Studies conducted at college of Agriculture Rajendranagar revealed that the seed yield of sunflower and castor did not differ significantly in all alley widths (3x3m,4.2x3m and 5.4x3m) when grown with *Fabled* in comparison 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. 2500 to 4500/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.3500 to 5000/ha could be realised. Intercropping of safflower in wheat increases the net returns by Rs.1000 to 1500/ha over sole crop of wheat.

Sesame: It can be raised as an intercrop with groundnut raised with 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.

5) 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 per 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 where as 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 per unit of area. Use of quality seed and fertilizer for oilseeds as well as 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 1141, 1178, 1303, and 1399 kg/ha in various sequences as against the national average productivity of 659 kg/ha during 1996-97. Similarly the groundnut and soybean yield in cotton-groundnut and rice-soybean sequence was 3453 kg/ha and 2451 kg/ha respectively compared to country's average productivity of 1150 kg/ha and 995 kg/ha in semi-arid ecosystem. The rapeseed-mustard productivity in coastal ecosystem was marked 1407 kg/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 crop 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. 41950/ha and Rs.40744/ha respectively by enhancing the system productivity. In Ujjain district of Madhya Pradesh and in the state of Manipur, black gram-mustard, soybean-wheat, and soybean-gram were found promising crop sequence having oilseeds as one of the component crop. In Maharashtra, the soybean was observed prominent oilseed crop associated with cereal, legume and other oil crops in the sequence. The per hectare income realized was Rs.20460, 27276, and Rs.33099/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 marked a common practice in eastern part of Uttar Pradesh. Soybean-wheat recorded almost similar net returns that of rice-wheat system in Punjab with high B:C ratio of 2.61 as against 2.41 in rice-wheat system.

6) 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).

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	621	1524	1073	34
Bud initiation stage	588	1598	1093	37
Flowering stage	613	1420	1017	27
Seed development stage	525	1329	927	16
Two irrigations at any of stages from 2-5	703	1649	1176	47
Three irrigations at any of stages from 2-5	804	1871	1338	67
Four irrigations at all stages from 2-5	941	2070	1506	88

Safflower yields can be doubled by providing two irrigations in Malwa plateau. In Western zone of Uttar Pradesh, raising of rice-mustard-mungbean for one year followed by rice-wheat-mungbean in succeeding two years registered in saving of water to the tune of 10.5% clearly favouring for the diversification of the rice-wheat system. 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 Jalander (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 (Table-7). 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 8). 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.

Table-6 Effect of rice based cropping systems on yield and resource use efficiency

Crop sequence	Rice equivalent Yield (t/ha)	Net income (Rs/ha)	B: C ratio	Land use efficiency (%)	Production Efficiency (kg/ha/day)	Energy Output: Input ratio
Rice-wheat-GM	11.54	29242	0.99	64.1	49.3	3.32
Rice-potato-sunflower	23.92	61553	1.31	81.4	80.6	3.21
Rice-mustard-sunflower	12.72	34066	1.21	86.6	40.3	3.49

Table-7 Effect of diversification of Rice-wheat cropping system on Resource Use Efficiency (Jalander)

Cropping System	Rice Equivalent yield(t/ha)	Economic Efficiency (Rs/ha/day)	Land Use Efficiency (%)	Irrigation water productivity(kg grain/ha/cm)	Nutrient productivity (kg grain/kg nutrient used)
Rice-wheat	9.28	84.7	76.6	72.1	18.9
Rice-potato-wheat	17.11	99.8	84.3	105.3	19.2
Rice-potato-sunflower	19.25	138.7	85.8	113.4	31.1

Table-8 Seed yield (kg/ha) and economics of oilseeds under nutrients and moisture stress

Crop	Centre	Rec.MC+FA	Farmer's method	% increase over F.M.	Additional net returns (Rs./ha)
Groundnut	Junagadh	2194	2035	8.0	1710
Soybean	Indore	2242	1765	27.0	4014
Sunflower	Raichur	974	773	26.0	4165
Castor	Mahabubnagar	926	741	24.9	1057
		Potential cultivar	**Check cultivar**	**% increase over check**	
Groundnut	Junagadh	2195	1944	12.3	5615
Soybean	Indore	2149	2048	5.0	1368
Sunflower	Raichur	998	761	31.1	3685
castor	Mahabubnagar	889	752	18.2	1207

Mean of two Years(2001-02 to 2002-03),MC= Moisture conservation, A= Fertilizer application

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 fertilizer requirement for succeeding sunflower needs suitable modification.

Role of tree species in nutrient conservation:

Trees can increase nutrient inputs to agroforestry systems by retrieval from lower soil horizons and weathering rock.

Increasing nutrient use efficiency:

Increasing the nutrient use efficiency through agroforestry can be achieved by;

- Increasing the cycling of nutrients from tree litter and prunings via the soil into the crops;
- Reducing losses by leeching;
- Reducing the losses by erosion.

The nutrient transfer from tree residues to crops is through litter and prunings. Perennial-crop combinations can provide 6-20t per ha per 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 20t in humid areas. Planted fallows can produce 12-30 t per ha per 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 per ha per yr. 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 per ha are N 120-150, P 20-25, K 80-100 and Ca 20-30 kg per yr. 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 per ha per yr (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 (Korwar and Radder, 1997). A saving of 9.5, 9.4 and 4.3 kg N to groundnut crop was observed when prunings were returned 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 per ha) in plots with *F. albida* trees (@ 625 trees per ha) than no tree control (0.69%, 16 kg and 162 kg per ha) in SAT (Korwar and Pratibha, 1999).

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