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Evaluation criteria of cropping systems and farming system models

K. Tejeswara Rao, D. Sekhar, M. Srinivas, A. Upendra Rao **and** G. Jogi Naidu
AICRP on Integrated Farming Systems, Agricultural Research Station, Seethampeta, Srikakulam (A.P.) India
(Email : tejaseniorscientist@gmail.com)

Farming systems represent an appropriate combination of farm enterprises *viz.,* cropping system, livestock, poultry, fisheries, forestry and the means available to the farmer to raise them for increasing productivity and profitability (Ghosh *et al.*, 1987 and Lightfoot, 1990). They interact adequately with the environment without dislocating the ecological and socio-economic balance on the one hand and attempt to meet the national goals on the other. Thus, the risk in dealing with single component can be minimized and at the same time increase the productivity through effective recycling.

The future of Indian agriculture depends heavily on the development of appropriate farming system as it fits to resource poor farm families of different agr-ecological zones. The endowment of abundant sunshine, long growing season, responsive soil types and combination of surface water, ground water and seasonal rains and above all a progressive peasantry offer vast scope for an intensive farming system through, multiple cropping and diversified farming including animal husbandry, forestry, sericulture, fisheries and the like.

With the World Trade Act coming into force, Indian agriculture is exposed to global market than ever before. The trend in international price suggest that to promote export, domestic prices must decline in terms of dollar in the long run and it is only possible with technological breakthrough or reduction in cost of production through crop shifts to efficient regions. In this situation farming system technology would be more helpful for improving present trend of export by producing the commodity at cheaper cost. In farming system by product of one enterprise are used as feed or nutrient for other, which directly influence the cost of production. Organic product would have better international market. The enhanced total production of farm through farming system any further reduce the cost of production and would have place in international market.

The overall objective is to evolve technically feasible and economically viable farming system models by integrating cropping with allied enterprises for irrigated, rained, hilly and coastal areas with a view to generate income and employment from the farm.

As a whole the concept of farming systems approach is to integrate farm enterprises for.

– Optimum utilization of resources.

– Minimize environmental pollution.

– Increase farmer's income.

– Create regular employment opportunities throughout the year.

– Increase export potential, support rural agro-industry and ultimately food security.

Criteria for evaluation of farming systems: To assess the dynamism and productive performance of farming systems, four criteria have been established, *viz.,*

– Productive criteria.

– Edaphic criteria.

– Economic criteria.

– Environmental or sustainable criteria.

Productive criteria: Productive criteria is further categorized in to

Quantitative productive criteria: Here, the production refers to the sum total of saleable economic yield + crop by products + produce from other component enterprises. The farm, which shows higher productivity, is the best farm according to quantitative productive criteria.

Ex: Mean productivity during previous year-16.0 t/ha

Productivity during current year-

Farm-I	Farm-II	Farm-III
14.0 t/ha	16.0 t/ha	18.0t/ha
(Deteriorating type)	(Balanced type)	(Improving type)

There are certain products, which fetch high price in the export market because of their quality. In such cases, quality alone should be considered. Qualitative productive criteria is more relevant incase of export oriented products, Nutritional output, nutritionally better quality etc.

Edaphic criteria: The three dimensional property of soil *viz.,* physical stability, chemical dynamics and biological health of the soil is taken in to consideration only in sustainable agriculture. The physical stability does not mean the physical intactness; it also refers to the soil being intact (no erosion). The chemical dynamism refers to the chemical inalterability towards degradation.

Illustration:

	Output	Erosion level (mmy-1)
System-I	18 t/ha	1.0 mm top soil
System-II	16 t/ha	0.4 mm top soil
System-III	14 t/ha	Negligible

System-III is rated as the best according to edaphic criteria, as it causes no degradation of soil resource. The output may be high in system-I, but it reduces the productive potential of the farm in the long run.

Economic criteria: Various economic tools like net returns, marginal rate of returns, linear programming, partial budgeting technique etc. can be applied for evaluation of the farming systems.

Net returns: Net returns alone may lead to wrong conclusions in view of the unique objectives set under farming systems management.

Crop	Net returns (Rs.)	Per day returns (Rs.)
Sugarcane (12 months)	12000/	33/-
Maize-maize-fallow	10000/-	55/-
Rice-groundnut-fallow	10000/-	55/-

Marginal rate of returns (MRR): An intelligent manager should also consider the marginal rate of returns.

Investment level	Investment volume (Rs.)	MRR (Rs.)
I	100/-	150/-
II	100/-	75/-
III	100/-	20/-
IV	100/-	5/-
V	100/-	5/-

Linear programming: Through it is an improved analytical economic tool that incorporates all the conditions and constraints in the existing situation and proposes various alternative by which one can increase the profitability of the system, it is not much useful to the farming system's manager, as it suggests the options for higher profitability, ignoring the very important productive and edaphic criteria.

Partial budgeting technique: Among the various economic tools, this is more useful for analyzing the performance of farming systems.

Preferred

Additional investment Additional returns

Preferred

Reduced investment Reduced returns

Partial budgeting technique is useful for comparing the existing practice with that of proposed practice. Any component or practice that is proposed should give additional yield or returns with additional or reduced investment.

Environmental criteria or sustainable: The term sustainability encompasses-

Edaphic biological sustainability: The important consideration in this that the soil should not be biologically reduced. A system that does not harm the microbial load is more important than any other beneficial things.

Indiscriminate use of agrochemicals like soil applied granules, soil drenching fungicides, etc. should be avoided. Persistent chemicals have no room under this criterion as they not only harm the existing microbial load but also affect the future microbial load.

Environmental quality: Drift hazard by plant protection chemicals, fumigants and other soil toxicants including fertilizers deteriorates the soil and aerial environmental and hence, the scope of using these chemicals is quite remote when this tool is applied for analysis of the systems performance.

Qualitative production sustainability: The edible products that are produced in the farming system should not be containing any residual toxicity as this tool takes in to consideration the residual toxicity of the agrochemicals.

Evaluation of cropping systems: Evaluated to find out their stability and relative advantage-

– Land use efficiency.
– Biological potential.
– Economic viability.
– Technical feasibility.
– Energetic approach, system modeling.

Land use efficiency:

Multiple cropping index/Multiple cropping intensity (*MCI*): It is ratio of total area cropped in year tot the total area available for cultivation and expressed in percentage (Dalrymple, 1971).

$$\mathbf{MCI} = \frac{\sum_{i=1}^{n} ai}{A} \times 100$$

i = 1,2,3, ……n, n= Total number of crops,

ai = Area occupied by i^{th} crop and

Table 1: Component of cropping systems evaluation

Land use efficiency	Biological potential	Technical feasibility	Economic viability	Energetic approach system modeling
Multiple cropping index (MCI)	Production efficiency (PE)	Choice of agro technology (CAT)	Monetary input output relationship (MR)	Promodernity index (PI)
Land utilization index	Crop equipment yield (CEY)	Resource demand (RD)	Diversity index (DI)	Pro industry index (PII)
Cultivated LUI (CLUI)	Relative yield total (RYT)	Resource availability (RA)	Harvest index	Energy efficiency index (EEI)
'R' Value	Land equipment ratio (LER)	Existing cropping system (ECS)	Relative net returns (INR)	Output parity index (OPI)
Cropping index (CI)	Staple land equipment ratio (SLER)		Simultaneous cropping index (SCI)	Energy intensiveness (EI)
Crop intensity index (CII)	Interference indices (II)		Income equivalent ratio (IER)	Renewable natural energy (RNE)
Specific crop intensity index (SCII)	Relative crowding co-efficient (RCC)		Bio-economic relationship (BR)	Fossil fuel based feed stock (FFBF)
Relative crop intensity index (RCII)	Aggressivity (A)			Nutritional energy equivalent (NEE)
Area time equivalency ratio (ATER)	Competition ratio (CR)			Energy ratios and indices (ERI)
Crop combination (CC)	Durability (D)			Investment ratio (IR)
Relative yield index (RYI)	Stability (S)			Energy productivity ratio (EPR)
Relative spread index (RSI)	Resilience (R)			Life style support energy (LSSE)

A= Total area available for cultivation.

Cultivation land utilization index (*CLUI*) : CLUI is calculated by summing the products of land area planted to each crop multiplied by the actual ill ration of that crop divided by the total cultivated land area, times 365 days.

$$MCI = \frac{\sum_{i=1}^{n} ai\ di}{A \times 365} \times 100$$

where, n = Total no. of crop, ai = Area occupied by ith crop, di= Days that the ith crop occupied ai and A= Total land area available in 365 days.

Cropping intensity index (*CII*): CII assesses farmers actual land use in area and time relationship for each crop or group of crops compound to the total available land area and time including land that is temporarily available for cultivation.

$$CII = \frac{\text{Gross cropped area}}{\text{Net area}} \times 100$$

Gross cropped area is area sown under different crops in different seasons in year on the available land. Ex. Farmer has 10 ha. Land and he has sown different crops.

Crops	*Kharif*	*Rabi*	Summer
Rice	5	4	-
Sorghum	5	5	-
Green gram	-	-	4
Raggi	-	-	2
Total	10	9	6

$$CII = \frac{26}{10} \times 100 = 260\%$$

$$CII = \frac{\sum_{i=1}^{n} ai\ ti}{Aot + \sum_{i=1}^{m} Aj\ TJ} \times 100$$

NC = Total number of crops grown by farmers during time period (usually one year)

ai = Area occupied by ith crop

ti = Duration of crop

Ao = Farmers cultivated land area

m = Total number of fields temporarily available

Aj = Land area of jith field

TJ = Time available for cultivation.

'R' value and cropping index (*CI*): As suggested by Ruthenberg (1976), the frequency of cropping in a fallow cycle and the cropping index *i.e.* the number of crops per year on a give field multiplied by 100 are identical.

Crop intensity index (*CII*) : It was proposed by Menegay *et al.* (1978). It assesses a farmers actual land use in areas of crops compared to the total available land areas and time including the land temporarily available for production.

$$CII = \frac{\sum_{i=1}^{Ne} ai\ ti}{Aot + \sum_{j=1}^{m} Ai\ Tj} \times 100$$

Ne ai ti CII AoT + M Ai Tj j=i

where, Nc = Total number of crops grown by a farmer during the time period T.

Ai = Area occupied by the ith crop

Ti = Duration of I th crop

T = Time period under study (Usually one year)

Ao = Farmers total cultivated land area available for use during the entire period T.

M = Total number of fields temporarily available for cropping during time period T.

Aj = Land area of j^{th} field.

TJ = Time period Aj is available.

Specific crop intensity index (*SCII*): SCII is a derivative of CII and determinates the amount of area- time denoted to each crop or group of crops compared to the total time available to the farmer (Menegay *et al.,* 1978)

$$SCII = \frac{\sum_{i=1}^{Nk} ak\ tk}{Aot + \sum_{j=1}^{m} Aj\ Tj}$$

where, NK = Total number of crops within a specific designation such as vegetable crops or field crops grown by the farmer during time period T.

ak = Area occupied by the K^{th} Crop.

tk = Duration of the K^{th} crop.

Using this formula vegetable intensity index, rice intensity index, field crops intensity index, etc. can be calculated.

Relative cropping intensity index (*RCII*): It is the another modification of CII and determines the amount of area-time allotted to one crop or group of crops relative to the area- = time actually used in the production of all the crops.

$$RCII = \frac{\sum_{k=1}^{Nk} ak\ tk}{\sum_{i=1}^{Ne} ai\ ti}$$

where, RCII numerator equals SCII denominator and RCII denominator equals CII numerator.

Staple land equivalent ratio (*SLER*): This concept is proposed when the primary objective of cropping system is to produce fixed yield of one component (Which is called staple and some yield other crop.

$$SLER = \frac{MDA}{SA} + P\left\{\frac{MB}{SB}\right\}$$

where, MDA is derived yield of A in mixture yield

"P" is the proportion of land devoted for intercropping.

Biological potentials:

– Production efficiency : (CEY, LER, RYT, SLER)

– Interference indices: RCC, A.CR D, S R.

Crop equivalent yield:

– The yields of different crops ;are converted into equivalent yield of any one crop based on price of produce.

$$CEY = \sum_{i=1}^{n}(yi.ei)$$

Yi- Yield of i^{th} component

ei- equivalent factor of i^{th} component or price of i^{th} crop

$$ei = \frac{pi}{pw}$$

pi- Price of unit wt of i^{th} crop

Pw – Price of unit wt of crop in which

Ex- yield of groundnut = 1000 kg.

Pigeonpea = 600 kg.

Total yield of interloping can be expressed in ground not equivalent yields by knowing price of each produce.

Price of groundnut Rs. 6/ kg.

Price of red gram Rs. 4/kg

EY of groundnut $\frac{1000 \times 6}{6}$ = 1000 kg

Ey of red gram $\frac{600 \times 4}{6}$ = 400 kg

CEY = 1000+ 400 = 1400 kg.

Land equivalent ratio: LER is the relative land area under sole crops that is required to produce the yield achieved in intercropping.

Yi- Yield of the component from unit area grown as inter crop.

YiJ – Yield of ith component grown as sole crop oven same area. In brief LER is the summation of rations of yields of intercrop to the yield old of sole crop.

Ex. yield of groundnut 1200 kg as pure crop

Yield of red gram 100 kg as pure crop.

Yield of groundnut grown as inter crop 1000

Yield of red gram grown as intercrop 600 kg.

LER of Gn + LER of red gram.

$$\text{LER of Gn} = \frac{\text{Yield of intercrop}}{\text{Yield of sole crop}} = \frac{1000}{1200}$$

$$\text{LER of redgram} = \frac{600}{3000} = 1.43$$

LER of 1.43 indicates that 43 per cent yield adventage is obtained when grown as intercrop compared to growing of sole crop.

LER of more than one indicate yield advantage equal to one indicate no gain no loss less than are indicate yield loss.

$$\text{LER} = \sum_{i=1}^{n} = \frac{yab}{yaa} + \frac{yba}{ybb}$$

LCR can be applied both for replacement services and additive series of intercrop.

LER is also termed as stretching of land area or Augmentation of law area through inters cropping.

LER: Provide :

– AS an index of combined yield, LER provides a qualitative evaluation of the yield advantage due to intercropping.

– Used to assess the competitive abilities of component species of intercrop

– LER could be used either as index of biological efficiency to evaluate effect of various agronomic practices on an intercrop system

– LER is identical to RYT and can be used for any set of intercropping treatments.

Disadvantage:

– LER is based on land area only does not take the duration of component crops into consideration.

– Several methods have been suggested for calculating LER using different sole crop values as standardization factors. The choice of sole crop of yield for standardizing mixture yield in estimation of LER is not clear and generalization is not possible.

– As an index biological efficiency LER is based on harvested products and not on desired yield proportion at sowing.

LER has also been used to calculate monetary advantage: The relative land area required as sole crops to produce the value of yields achieved in inter cropping.

$$\text{Monetary advantage} = \text{Value of combined intercrop yield x } \frac{\text{LER} - 1}{\text{LER}}$$

Area time equivalent ratio: It takes into account the duration of crop and permit evaluation of crops on yield per day basis. It is modification of LER.

$$\text{ATER} = \frac{\text{LA x DA} + \text{LB x DB}}{\text{T}}$$

where, LA and LB are relative yields or partial LER of component crops a A and B DA and DB are duration of crop A and B and T is the total duration of inter cropping system.

After is ratio of number of hectare – days required in monoculture to number of hector days used in the intercrop to produce identical quantities of each of component crop.

After: 1 indicate more efficient use of area time by intercrop.

Relative yield total (*RYT*) : The mixture yield of a component crop expressed as a portion of its yield as a sole crop from the same replacement services is relative yield of the crop and sum of relative yields of component crop is called RYT.

$$\text{RYT} = \frac{\text{Yab}}{\text{Yaa}} + \frac{\text{Yba}}{\text{Yaa}}$$

Yaa = Yield component as a sole crop.

Ybb= -----------”------------b.-----------”-----------

Yab= -----------”-------------‘a’ as intercrop in b

Yba= -----------”-----------‘b’-----------”--------- in a

In pasture mixture of stylo and Anjan grass grown 1:1 ratio *i.e.* 50 per cent of sole crop population of both crop.

– Yield of stylo and Anjan grass sin mixture are 6 and 4 ton green fodder.

– Their sole crop yield at 100 per cent population are and 8 tons, respectively.

$$\text{RYT} = \frac{\text{Yield of stylo and Anjan grass in mixture}}{\text{Yield of stylo and Anjan grass in pure stand}}$$

Yields of crops in mixture at 50 per cent population of stylo and Anjam grass were 6 and 4 t/ha and their corresponding yield would be 12 and 8 at 100 per cent population.

$$\text{RYT} = \frac{12+8}{10+8} = \frac{20}{18} = 1.11$$

Relative crowding co-efficient: Aggressivity can also be used competition index to evaluate the completion ratio productivity of cropping systems.

Relative crowding co-efficient: RCC can be defined in terms of LER component as:

$$\text{RCC} = \frac{\text{LA}}{1-\text{LA}} \text{x} \frac{\text{LB}}{1-\text{LB}}$$

The two indices of dominance are the aggressivity and competition index aggressivity and competition index.

Aggressivity gives a simple measure of how much the relative yield increase in species A is greater than that of species B. It is an index of dominance. For replacement series it can be written as :

$$\text{Aggressivity} = \frac{\text{Mixture yield of A}}{\text{Expected yield of A}} - \frac{\text{Mixture yield of B}}{\text{Expected yield of B}} = \frac{\text{MA}}{\text{SA x ZA}} - \frac{\text{MB}}{\text{SB x ZB}}$$

Sown proportion of species A and B are represented as ZA and ZB, respectively.

Relative yield index (*RYI*):

$$\text{RYI} = \frac{\text{Mean yield for the crop in a district/Group of districts}}{\text{Mean all India yield}} \times 100$$

Relative spread index (*RSI*):

$$\text{RSI} = \frac{\text{Area of crop expressed as percentage of the total cultivated area in the zone}}{\text{Area of the crop expressed as percentage of total cultivated area in the country}}$$

Relative crowding co-efficient (*RCC*):

The relative crowding co-efficient in terms of LER compound can be defined as: $= \frac{\text{LA}}{1 - \text{LA}} - \frac{\text{LB}}{1 - \text{LB}}$

Aggressivity index:

It gives the measure of how much the relative yield increase in species A is greater than that for series B It is an index of dominance. For replacement series it can be written as.

$$\text{Aggressivity} = \frac{\text{Mixture yield of A}}{\text{Expected yield of A}} - \frac{\text{Mixture yield of B}}{\text{Expected yield of B}}$$

$$= \frac{\text{MA}}{\text{SA x ZA}} - \frac{\text{MB}}{\text{SB x ZB}}$$

Where, ZA and ZB are sown proportions of species A and B, respectively. An aggressivity value of zero means that the component species are equally competitive.

Economic viability: The indices like ER, RYT gives biological suitability of C.S in an area. At the same times GS should be economically viable and profitable.

Gross returns: The total monetary value of economic produce and by produced from the crops raised in CS is calculated based on local market price.

The total return is expressed in terms of nit are, usually one ha.

Cost of cultivation: Total expenditure incurred for raising crops in CS.

Own hired human labour, unlock, seed manures, fertilizer, pesticides, herbicides and irrigation.

Net returns or net profit: Net return is obtained by submit acting cost of cultivation from gross returns. It is good indicator of usability of a cropping system since the represent the actual income to former generally in this type of calculations only the variable costs are considered. Fixed costs such a sent for land, land revenge interest on capital etc are not included for realists estimate however, fixed coot should also be included.

Cost –befit ratio: Is the ratio of gross return to cost of cultivation or returns per Rs. Invested any value above 2 is considered safes the farmer gets Rs. 2 for every rupee invested.

$$\text{Returns per rupee invested} = \frac{\text{Gross returns}}{\text{Cost of cultivation}}$$

$$\text{Per day return} = \frac{\text{Net returns}}{\text{Cropping period (days)}}$$

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