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# GAP ANALYSIS IN FARMING SYSTEMS : PROBLEMS AND APPROACHES

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# GAP ANALYSIS IN FARMING SYSTEMS : PROBLEMS AND APPROACHES†

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## Introduction

The International Rice Research Institute (IRRI) has developed a set of concepts and methodologies to analyze the causal factors between differences in experimental yields and yields at farmers' field levels *for a specific crop* (Yield Gap Analysis). The methodologies are aimed at evaluating mainly the impact of factors under the farmer's control, and not at studying environmental factors such as water control, etc.

Until recently high yielding varieties of dry land crops had been adopted by farmers only in a few selected regions of India. Hybrid sorghums have now spread more broadly especially in Maharashtra. Where high yielding genotypes have been adopted, single crop gap analysis of the IRRI type is clearly appropriate and the research design will require only minor modifications.

Based on the IRRI methodology, this paper first outlines basic problems for gap analysis in the *context of Farming Systems*, including specifically the evaluation of gaps due to intercropping and alterations in soil management treatments. It then uses ICRISAT research results to (i) illustrate potential difficulties and (ii) to get a first impression of the magnitude of such gaps.

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## Section 1. Basic Issues of Gap Analysis for Farming Systems

In dealing with systems of farming the first problem is one of *definition of yield.* If a system contains more than one crop, or even more than one variety of a crop, one cannot add up yield, but must use value of output or *gross return* as a yardstick. Thus we must talk of *return gaps* and not yield gaps. This immediately poses the problem that prices vary from year to year, from location to location or may be distorted by government policies.[1] How to deal with this issue depends on the purpose of the analysis:

a) For comparisons within a location (and when price distortions are not to be considered) one should not use prices from an individual year, because that will jeopardise year to year comparability of results. One can of course value outputs (and inputs) at the prices of one single year for all years of the experiment. But it is preferable to use average prices over a number of years, after adjusting them for inflation via an index of farm harvest prices.

b) For comparisons across locations all prices should be the same for all locations. Across location comparisons are relevant primarily for potential return, as measured either in farmers' fields or in experiment stations. Gaps in potential return would be linked to non-transferability of technology or to irreducible environmental differences.

c) In cross-country comparisons the problem of common prices will be especially severe, since many countries distort agricultural prices by policies. World market prices over a number of years or an average of the participating countries prices will have to be used.

Varieties of a crop are not equally adapted to all locations. Comparison of yield potentials across locations in gap analysis raises the issue of which varieties should be compared. Such comparisons should

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[1]Note that the yield definition problem exists even for single crops if the byproduct has a considerable value and relative prices of product to byproduct varies across locations or over years.

be based on the best adapated variety for each of the locations studied. For an example, see Barker (1979), tables 4 and 5.

For cropping systems the problem is more complex. Clearly it is inappropriate to judge potential of locations on the basis of a uniform system. Instead such comparisons need to be *based on optimum cropping systems for each location.*

Within any location it similarly makes little sense to analyze return gaps of new farming systems with existing ones, unless the new systems are optimal for the location. *A prior condition for any gap analysis is the development and testing of optimal farming systems for each location.*

Agronomic components of a system can usefully be evaluated in small plot experiments. Evaluating intercropping systems already requires larger plot sizes. Experiments including soil-water treatments require even larger plot sizes. This implies that it will be virtually impossible to do gap analysis experiments in which the last two components are set at more than the optimal system is therefore particularly important for the cropping system and the soil-water management systems to be adopted.

Section III will use ICRISAT data and simulation models to more closely define optimal systems for several locations with special emphasis on the cropping system and soil water management components. Before turning to it, the nature of the ICRISAT data is briefly discussed.

## Section 2. Data and Experiments

ICRISAT has not conducted any experiments aimed at Gap Analysis. Instead all effort has been devoted to designing optional farming systems. We will use the data therefore mostly for that purpose in Section 3. However, in section 4 we will try to glean as much about gaps from the data as we can. The data come from several sources.

1) Steps-in-Improved Technology Experiments. The input-output data for the economic analyses of the steps-in-improved technology experiments were generated collaboratively by staff of the Farming Systems Research Program and the Economics Program of ICRISAT. The objective of these experiments was to measure the individual and complementary effects of the various components of prospective agricultural technology for the SAT. The plot sizes are fairly large ranging from 0.07 to 0.1 ha, which enable the soil and crop management treatments to express themselves.

The four basic treatments in the SIIT experiments were (1) variety, (2) fertilization, (3) soil and crop management and (4) water management. Each of these four basic treatments was examined at two levels in a factorial experimental design. One was aimed at simulating local practice (L) and the other the improved technology (I). More detailed explanation and presentation of complete results can be found in Ryan, Sarin (1977) and Ryan, Sarin and Pereira (1979).

2) Center Watersheds. The operational watershed experiments on a field scale at ICRISAT Center aim to test the soil and water management aspects of prospective technology. Small agricultural watersheds, ranging in size from 0.3 to 11 ha have been the conceptual focus of this phase of research of the Farming Systems Research Program in ICRISAT. The input output data on these large plots were

monitored and analyzed (Ryan, Sarin and Pereira 1979) to enable major comparisons of economic interest, viz. (i) relative performance of the graded broad bed and furrow (BBF) method of cultivation compared to the traditional flat techniques across the slop and/or on the contour, (ii) effects of different graded slopes of broad bed and furrows, (iii) effects of different types of bunds -- contour, graded, field, etc.

3) Village Watersheds. In view of the qualitative differences in the factor endowments of farmers' compared to research stations, the performance of technology in farmers' fields may differ from what has been observed at research stations. Therefore in 1978 a small-scale farming systems research project was initiated on one farmer's holding on one watershed in each village of three districts: an Alfisol area in Mahbubnagar with rainfall similar to Hyderabad, a low rainfall kharif fallow area in Sholapur with Vertisols, and another Vertisol area in Akola with assured rainfall. The villages are those of the Village Level Studies (VLS) program of ICRISAT. The plot sizes ranged from 0.08 to 0.15 ha. The treatments compared were (i) sowing on flat with local equipments, (ii) sowing on flat with improved implements and seed fertilizer attachment, (iii) sowing on beds with improved implements and seed fertilizer attachment. The data relate to the year 1978 which was the first year of experiment. Some of the cropping systems were far from optimal and other experimental problems existed. Conclusions based on the data are therefore tentative.

4) Village Level Studies. In the same villages where we have village watersheds the Economics Program of ICRISAT has been conducting village level studies (VLS). (In each of the regions an unaffected control

village is also studied.) The emphasis of the VLS has been on assessing the resource position of households and monitoring resource use and farming practices with a view to understanding the economic, institutional, social and biological influences in traditional farming systems. The VLS are primarily designed to collect relevant farm level details to assist ICRISAT's research system which is engaged in the task of generating technology suited to the needs and means of SAT farmers.

Since 1974 data has been collected regularly from 40 respondent households (30 cultivator, 10 labor) on various aspects of farming practices and household economics. For this paper we have selected the two dominant cropping patterns in each region, one for food crops and other for cash crops, which will be compared with experimental results. For more details on the Village Level Studies see Jodha, et al. 1977.

5) Soil Moisture Simulation. In the semi-arid tropics the soil moisture regime is a particularly important determinant of the farming system. At ICRISAT substantial work on improving soil moisture simulators and adapting them to the prevailing soil types has been done. A whole soil profile simulator based on Fitzpatrick and Nix (1969) was initially used at ICRISAT and a new model has been developed by Reddy (1979) and is now widely used by several sections of ICRISAT.

M. B. Russell and the soil physics group at ICRISAT has done basic work on water movements in the soils and built an operational soil moisture simulator for the top 30 cm of soil. Results based on both simulators are used below.

## Section 3. Towards Optimal Systems for Selected Locations

ICRISAT has experimented substantially with runoff collection for supplementary irrigation. The complexity of such systems make them unsuitable for gap analysis and we will not further consider them here.[1]

One of the regions where ICRISAT conducts village research is the "low rainfall" kharif fallow area of Sholapur. While the "high rainfall" kharif fallow belt of Northeastern Maharashtra and Madhya Pradesh has considerable potential for kharif cropping, soil moisture probabilities virtually rule out kharif cropping in the low rainfall kharif fallow belt. This can be shown using probabilities of favorable soil moisture conditions based on the two soil moisture simulators discussed in section 2 and historic rainfall data for the respective regions.

Table 1 presents probabilities of crops surviving certain stages or having good soil moisture regimes. The probabilities may not measure risk precisely but represent orders of magnitudes of potential and risk which can be compared across locations and lead to clear inferences.

Column 4 shows the total probability of a 90-day crop encountering good growth conditions throughout the growth period. At Sholapur in the low moisture kharif fallow region this is the case only in roughly 1/3 of the years, whereas both in Hyderabad and Akola it is the case for 2/3 of the years. The biggest disadvantage in Sholapur arises from a much lower probability of emergence before July 15 (column 1) which can happen in only 2/3 of the years. But as all subsequent conditional probabilities (not shown) are lower so that the plant is at a higher risk in Sholapur than in the other two areas at every stage after it has completed the earlier stages successfully.

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[1] In a recent synthetic exercise using ICRISAT research it was also found that runoff collection for supplementary irrigation has very little potential on Vertisols. In the future such research will primarily be oriented towards Alfisols.

Table 1. Reliability of a 90-day kharif crop - Vertisols of three areas

(in percent of years)

| | Probability of emergence to July 15 | Probability of seedling survival | Probability of adequate soil moisture thru growing period | Probability of good growth condition | Probability of adequate soil moisture after kharif crop | Probability of adequate soil moisture after kharif fallow |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Sholapur deep Vertisols* | 65 | 49 | 41 | 33 | 60 | 80 |
| Hyderabad deep Vertisols* | 85 | 76 | 69 | 62 | 50 | n.a |
| Akola medium Vertisols* | 92 | 80 | 74 | 66 | n.a | n.a |

*Water-holding capacity for deep and medium deep Vertisols 230 mm and 120 mm respectively.

Notes to columns:

(1) Assuming dry seeding and using 1 inch of rainfall as sufficient for emergence.

(2) Defined as no water stress in top soil layer for 2 weeks after emergence.

(3) Soil moisture more than 50 mm during all weeks.

(4) Probability of fulfilling all previous conditions.

(5) Total probability of having more than 150 mm of stored water between mid-September to mid-October after growing a kharif crop.

(6) As (5) but with kharif fallow.

A 33% probability of a good soil moisture regime is too low a basis for encouraging kharif cropping on a year after year basis. Further note that probabilities of good soil moisture for a rabi crop after kharif fallow (column 6) are a high 80% in Sholapur which exceeds the total probabilities of good growth conditions for kharif crop in Hyderabad or Akola (column 4). However, if a kharif crop is taken in Sholapur, the chances of the rabi crop are reduced by 20%. Not only would consistent kharif cropping not be profitable, but it would also endanger the profitability of a more important rabi crop. Cropping systems for the low rainfall kharif fallow therefore need to emphasize the rabi crop.

In most years therefore the soils will be fallow during the kharif season in low moisture kharif fallow areas and will be subject to serious erosion hazards. A soil-water management system in that region will probably include graded or possibly even contour bunds, to minimize erosion from the fields and maximize retained moisture. Furthermore, center watershed research indicates that *under fallow conditions* a broad bed and furrow (BBF) system substantially increases infiltration (a vital goal for rabi cropping on residual moisture) and reduces erosion. Therefore an optimal system in Sholapur is likely to contain BBF as well as the bunds.

On the other hand, a synthetic analysis of SIIT and Center watershed experiments has recently concluded that BBF are unlikely to reduce erosion and soil loss or to increase yield and profits in Alfisols and on medium deep and shallow Vertisols when crop cover exists. The absence of striking profitability of the BBF system under such conditions is further confirmed by the village watershed results for 1978-79. (Table 2, based

Table 2. Impact of implements and Broad Beds and Furrows (BBF)

| Increases Due to: | Village Watersheds 1978-79 — Gross Returns: Pigeonpea Sorghum Intercrop | Castor | Pigeonpea P. Millet Intercrop | Gross Profits* (Rs/ha): Pigeonpea Sorghum Intercrop | Castor | Pigeonpea P. Millet Intercrop |
|---|---|---|---|---|---|---|
| | | | MAHBUBNAGAR, ALFISOLS | | | |
| Implements** | 900 (41) | 470 (56) | 966 (213) | 777 | 407 | 825 |
| Broad Beds and Furrows*** | 182 (6) | 235 (18) | (-66) (-5) | 191 | 292 | (-54) |
| | | | AKOLA, MEDIUM DEEP VERTISOLS, ASSURED RAINFALL | | | |
| | | Maize | Kharif Sorghum | | Maize | Kharif Sorghum |
| Implements** | 328 (19) | 356 (44) | 170 (11) | 281 | 299 | 103 |
| Broad Beds and Furrows*** | 256 (13) | (-128) (-11) | 60 (3) | 271 | (-137) | 42 |
| | | | SHOLAPUR, DEEP VERTISOLS, UNCERTAIN RAINFALL | | | |
| | | Mungbean followed by Sorghum | Rabi Sorghum | | Mungbean followed by Sorghum | Rabi Sorghum |
| Implements** | 814 (28) | 1120 (83) | 110 (9) | 1230 | 734 | (-151) |
| Broad Beds and Furrows*** | 88 (2) | (-65) (-3) | 254 (19) | 142 | 135 | 141 |

* Gross profits are defined as gross returns less costs for material inputs, machinery, bullock and human labor. (Prices are same for all locations).

** Changing from traditional to improved implements on flat.

***Changing from flat to broad beds and furrows (BBF) with improved implements.

Numbers in parentheses are percentage changes with gross returns of lower technology level as basis for percentage change.

on Appendix tables 1, 2 and 3). The gross return and gross profit differences caused by improved implements (wheeled tool carrier with attached tools and seed-fertilizer drill) are largest in Mahbubnagar on the Alfisols and Sholapur on deep Vertisols. Nowhere are the additional increments achievable by broad beds and furrows substantial and they are sometimes negative. A reversal of these conclusions occurs only for rabi sorghum in Sholapur.

These results suggest that the BBF system would not be part of an optimal farming system in Alfisol and medium deep Vertisol areas where its profitability has not been confirmed and where crop cover alone is usually sufficient erosion protection.

The type of information in table 2 obviously has two uses: the first is towards defining optimal practices. But it also establishes one portion of the returns gap. We will come back to this in the conclusion.

Based on earlier experience, intercropping of sorghum and pigeonpea appears to be the most promising cropping pattern for Alfisols in the Hyderabad-Mahbubnagar area. Much of the SIIT experimental work at ICRISAT was based on that assumption. Farmers' traditional practice is also consistent with this, although their mixtures often include additional crops. Appendix table A-1 also indicates superiority of sorghum intercropped with pigeonpea to a similar combination with millet.

For Hyderabad Vertisols the considerable experience of the FSRP suggests that a maize-pigeonpea intercrop is optimal both for deep as well as medium deep Vertisols.

For Akola medium deep Vertisols, table A-2 suggests that maize may not do as well there as in Hyderabad compared to sorghum. Furthermore, in that area sole HYV sorghum has been fairly widely adopted by farmers and should probably be considered. The traditional system is a cotton dominated

Table 3. Predicted farming systems for selected areas

| Regions similar to soil type | KHARIF FALLOW | | Hyderabad-Mahbubnagar | | Akola |
|---|---|---|---|---|---|
| | Sholapur (Low rainfall) Deep Vertisols | Madhya Pradesh (High rainfall) Deep Vertisols | Deep Vertisols | Alfisols | Medium to Shallow Vertisols |
| Soil water management | Broadbeds and furrows<br>Guide bunds<br>Land smoothing<br>Grassed waterways<br>Emphasis on erosion control and infiltration | Guide bunds<br>Broadbeds and furrows to be tested<br>Land smoothing<br>Grassed waterways<br>Emphasis on drainage | Broadbeds and furrows<br>Guide bunds<br>Land smoothing<br>Grassed waterways | Flat cultivation, except where supplemental water is available<br>Guide bunds<br>Land smoothing | Guide bunds<br>Land smoothing<br>Grassed waterways<br>Cultivation and tillage to be investigated |
| Cropping system | Rainy season fallow (possibly short duration low input rainy season crop in some years) | Potential for rainy season cropping to be investigated | Preferably rainy season crops with intercrops | Rainy season crops with intercrop | Rainy season crop with intercrop |
| Agronomic practices | ---Based on nearby experiment station results--- | | | | |

mixture which includes sorghum and pigeonpeas. Clearly a more precise definition of an optimal pattern is not possible without data from the local experiment stations on farmers' fields.

For deep Vertisols in Sholapur we have already excluded kharif crops on a year after year basis. The local experiment station recommends early sowing of an HYV rabi sorghum, whereas current farmer practice is a somewhat later planting of local varieties of rabi sorghum. In selected high rainfall years the sorghum could be preceded by a short duration crop such as mungbean.

The conclusions from this section are summarized in Table 3 as "predicted" farming systems which must be considered tentative. We emphasize the fact that for locations away from Hyderabad the basis for this is predicted systems does not yet include a full analysis of the data from nearly experiment stations. Such an analysis could help define the systems more clearly. Nevertheless we doubt that these optimal systems could ever be settled to the satisfaction of all scientists engaged in a gap analysis exercise.

A further difficulty is that in each case, the optimal systems described in table 1 would rarely apply to more than 1/2 of a farmers area or production. Except in Sholapur, cash crops and/or rice are probably more important as a scurce of farmer's incomes than the dryland food crops. And in Sholapur rabi cropping is confined to the deep Vertisols while the other soils are mainly put to pigeonpea, millets and groundnuts. We will again return to this issue later on.

## Section 4. Gaps Observable with ICRISAT Data

In Table 4 we have put together data from Center watersheds with data for village watersheds and farmer's field data using the best available systems for comparison with watersheds and keeping soil type constant. Note, however, that in the case of Akola and Sholapur the distances between center and village are such that optimal systems inevitably change, as has been illustrated in table 3. Note further that in particular the village watershed data are weak because they come from one year only.

The IRRI methodology distinguishes two gaps; Gap 1 is the difference between potential farmer yield and experiment station yield and is ascribed to irreducible environmental differences. With the exception of the Alfisols our data are not very good to measure Gap 1, because the experiment station yields should come from nearby experiment stations rather than from a distant center. Therefore, environmental differences (caused primarily by rainfall patterns) are confounded with the differences between experiment station and farmers' fields. The smallest Gap 1 difference is on the Alfisols with the village watershed using sorghum pigeonpea intercrop. It is approximately Rs. 700 or about a 20% reduction in "potential."[1] The largest difference of Rs. 3,400 (i.e. 68% reduction) is in the comparison with rabi Sorghum on the deep Vertisols. Clearly much insight can hardly be

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[1]Note, however, that we now know that at Center an intercrop generally does better than a sequential crop on these soils.

Table 4. Gross returns, variable costs and gross profits in rupees per hectare from different cropping systems at experimental and farm level*

| | Cropping System | Gross Returns | Total Variable Cost | Gross Profit | Returns Gap I | Returns Gap II |
|---|---|---|---|---|---|---|
| <u>Mahbubnagar (Aurepalle)</u> <u>Alfisols</u> | | | | | | |
| Village watershed[a] | Castor Sole (HYV) | 1316 | 773 | 543 | 2442 (65) | |
| Farmer[b] | Castor Sole (Local) | 326 | 339 | (-13) | | 990 (75) |
| Village watershed[a] | Pigeonpea intercropped with Sorghum (HYV) | 3086 | 775 | 2311 | 672 (18) | |
| Farmer[b] | Sorghum Mixtures (Local) | 421 | 248 | 173 | | 2665 (86) |
| Center watershed[c] | Sorghum followed by Safflower (HYV) | 3758 | 1561 | 2197 | | |
| <u>Akola (Kanzara)</u> <u>Medium Deep Vertisols</u> | | | | | | |
| Village watershed[a] | Sorghum (HYV) | 1788 | 765 | 1023 | 2400 (57) | |
| Farmer[b] | Sorghum (HYV) | 1425 | 562 | 863 | | 363 (20) |
| Village watershed[a] | Pigeonpea intercropped with Sorghum (HYV) | 2042 | 829 | 1213 | 2146 (51) | |
| Farmer[b] | Cotton Local+Local Sorghum+Pigeonpea (Local) | 701 | 768 | (-67) | | 1341 (66) |
| Center watershed[d] | Pigeonpea intercropped with Maize (HYV) | 4188 | 1277 | 2911 | | |

Contd...

Table 4 continued...

| | Cropping System | Gross Returns | Total Variable Cost | Gross Profit | Returns Gap I | Returns Gap II |
|---|---|---|---|---|---|---|
| Sholapur (Shirapur) Deep Vertisols | | | | | | |
| Village watershed[a] | Sorghum Rabi (HYV) | 1606 | 1080 | 526 | 3423 (68) | |
| Farmer[b] | Sorghum Rabi (Local) | 396 | 250 | 146 | | 1210 (75) |
| Village watershed[a] | Pigeonpea[e] (HYV) | 3806 | 1123 | 2683 | 1223 (24) | |
| Farmer[b] | Pigeonpea (Local) | 282 | 88 | 194 | | 3524 (93) |
| Center watershed[d] | Pigeonpea intercropped with Maize (HYV) | 5029 | 1298 | 3731 | | |

[a]Watershed data in the flat planted treatment of tables A-1 to A-2 refer to 1978-79.

[b]Farmers' data come from large samples for the years 1975-76 and 1976-77

[c]Relates to 1977-78 only.

[d]Data relate to systems with BBF and are three years' average of 1976-77 to 1978-79.

[e]Watershed data on BBF from table A-3 and refers to 1978-79. This is from an intercrop with kharif sorghum where sorghum failed due to shootfly.

*Prices are same for all locations.

Figures in parentheses are percentage differences.

gained in Gap 1 analysis from this data set.

Gap II refers to the difference between potential farm yields and actual farm yields. Our data are better suited to this comparison. Table 4 shows a sharp contrast between the Akola situation on the one hand and the Sholapur and Mahbubnagar situation on the other hand. In Akola, a fairly assured rainfall region oriented to cash crop, farmers investment levels in these crops are substantial and only somewhat lower than those used in the village watersheds. In the case of HYV sorghum the yield gap is Rs. 360 or 25% only. The second Akola comparison is between a cotton mixture containing sorghum and pigeonpea for the farmers and a HYV sorghum pigeonpea intercrop. Here, with virtually the same investment level, the village watershed achieves nearly a threefold output. Even with all qualifications in our data this indicates a very large scope for improvement. Appendix table A-4 (column 2) shows that the improvement has come from genotype-fertilizer change.[1]

In Sholapur district farmers inputs are at most 25% of the village watershed inputs and the major proportion of the difference may be due to the near total lack of fertilizer applications by the farmers. The output differences are very large although in the case of pigeonpea the village watersheds were conducted on an unusually good soil in a favorable year. It appears to be important to find out the causes of the low investment levels of farmers, and measure potential gross returns more precisely.

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[1]Within a given genotype (or crop combination) there are of course many other factors causing gaps across farms, a problem analyzed in a different way by Ghodake (1980).

The case of Mahbubnagar is similar to Sholapur in that investment levels of farmers are less than 50% of village watersheds, again because farmers use virtually no fertilizer. And again the output differences are substantial in the case of **the** sorghum pigeonpea intercrop. Note here that the farmers use traditional genotypes while improved genotypes are used on the village watersheds.

Overall Table 4 is unsatisfactory in many ways. Nevertheless it suggests the importance of genotype and fertilizer changes.

## Summary

This paper is addressed to the potential and difficulties of IRRI type gap analysis for cropping or farming systems. Section 1 listed two major problems, the first being one of valuation of outputs rather than simple yield measurement. The solutions to the valuation problem consists of measurements of gaps in terms of gross returns instead of yields with the precise valuation rules depending on the context of the analysis. The second major difficulty, faced to a lesser extent by monocrop gap analysis, is the necessity of defining an optimal system with which to compare the farmer's systems. We note here that if one has such a system, gap analysis similar to the monocrops systems can indeed be used despite the fact that optimal systems may contain different crops and other differences across regions or relative to farmer's practice.

The second and third section of the paper attempted to define such optimal systems where ICRISAT is engaged in collaborative work at the village level. Substantial difficulties were encountered, which could partly be overcome by a more judicious use of regional experiment station data. Nevertheless the exercise highlights the location specificity of any of these optimal systems.

Even with more extensive use of regional experiment station data it would be difficult for a team of scientists to fullheartedly agree on optimal systems. Furthermore for unirrigated situations such systems may often apply to less than one half of a farmers land. This is because of the heterogeneity of the land base with farms in most of the SAT, because farmers may have irrigated lands as well and because they may have to maintain a balance between cash and food crops. This is in sharp contrast to the primarily rice based farming system studied by IRRI.

In the last section we noted the difficulties of doing gap analysis with data not explicitly derived for that purpose. Nevertheless the little data which we presented tended to suggest that the largest gaps may be associated with variety and fertilizer differences. Should we then push for gap analysis in farming systems at this stage, given all the difficulties encountered?

We contend that an alternative course of action may be more productive. With the exception of a few locations in the SAT, optimal farming systems are still quite ill defined. Furthermore, as new genotypes and more information on soil-water management systems may become increasingly available, the optimal systems may change rapidly from what is perceived as optimal now. The experience of ICRISAT and other centers tends to suggest that a strong on-farm research component is essential to derive optimal systems any way. Such on-farm research may often consist of special purpose smaller scale experiments similar to the one reported in table 2 which was aimed at identifying crucial components of the system. But if you have such experiments including farmers' treatments and otherwise have access to a good village data base, would you not accumulate sufficient information on components of the gaps in the process of defining an optimal system so that an *ex-post* analysis of the system becomes unnecessary?

We believe that this may indeed be the case, and would, at this stage, recommend that no IRRI-type gap analysis strategies be used in farming systems research. On the other hand, where high yielding genotypes have already been adopted to a substantial extent, individual crop oriented gap analysis may now be appropriate, as in the case of HYV sorghum or cotton in major portions of Maharashtra. Where such crops are traditionally grown as mixtures, problems of analyzing them in the intercrop context may still arise. In selected cases where good information exists on an optimal intercropping pattern with the new genotypes, the crop oriented gap analysis could still take place in the clearly defined intercrop context.

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Appendix Table A-1. Mahbubnagar (Aurepalle)

| Crops | Material Cost (Rs/ha) | Machinery & Labor Cost (Rs/ha) | Total Variable Cost (Rs/ha) | Total Gross Returns (Rs/ha) | Gross Profit (Rs/ha) |
|---|---|---|---|---|---|
| <u>Pigeonpea intercropped with sorghum</u> | | | | | |
| Beds (TC)[a] | 590 | 176 | 766 | 3268 | 2502 |
| Flat (TC) | 576 | 199 | 775 | 3086 | 2311 |
| Flat (TI)[b] | 562 | 89 | 651 | 2186 | 1535 |
| <u>Castor</u> | | | | | |
| Beds (TC) | 517 | 198 | 715 | 1551 | 836 |
| Flat (TC) | 588 | 185 | 773 | 1316 | 543 |
| Flat (TI) | 572 | 139 | 711 | 846 | 135 |
| <u>Pigeonpea intercropped with pearl millet</u> | | | | | |
| Beds (TC) | 441 | 235 | 676 | 1354 | 678 |
| Flat (TC) | 443 | 246 | 689 | 1420 | 731 |
| Flat (TI) | 352 | 195 | 547 | 454 | (-93) |

TC = Tropicultor

TI = Existing Farm Equipment

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Appendix Table A-2. Akola (Kanzara)

| Crops | Material Cost (Rs/ha) | Machinery & labor cost (Rs/ha) | Total variable cost (Rs/ha) | Total gross returns (Rs/ha) | Gross profit (Rs/ha) |
|---|---|---|---|---|---|
| Pigeonpea intercropped with sorghum | | | | | |
| Beds (TC)[a] | 612 | 202 | 814 | 2298 | 1484 |
| Flat (TC) | 612 | 217 | 829 | 2042 | 1213 |
| Flat (TI)[b] | 612 | 170 | 782 | 1714 | 932 |
| Kharif Maize | | | | | |
| Beds (TC) | 561 | 279 | 840 | 1036 | 196 |
| Flat (TC) | 561 | 271 | 832 | 1164 | 332 |
| Flat (TI) | 561 | 214 | 775 | 808 | 33 |
| Kharif Sorghum | | | | | |
| Beds (TC) | 577 | 205 | 782 | 1848 | 1066 |
| Flat (TC) | 571 | 194 | 765 | 1788 | 1023 |
| Flat (TI) | 571 | 127 | 698 | 1618 | 920 |

TC = Tropicultor

TI = Existing Farm Equipment

Appendix Table A-3. Sholapur (Shirapur)

| Crops | Material cost (Rs/ha) | Machinery & labor cost (Rs/ha) | Total variable cost (Rs/ha) | Total gross returns (Rs/ha) | Gross profit (Rs/ha) |
|---|---|---|---|---|---|
| Pigeonpea intercropped with sorghum | | | | | |
| Beds (TC)[a] | 777 | 346 | 1123 | 3806 | 2683 |
| Flat (TC) | 826 | 351 | 1177 | 3718 | 2541 |
| Flat (TI) | 1120 | 473 | 1593 | 2904 | 1311 |
| Mungbean followed by sorghum | | | | | |
| Beds (TC) | 904 | 521 | 1425 | 2400 | 975 |
| Flat (TC) | 1076 | 549 | 1625 | 2465 | 840 |
| Flat (TI) | 847 | 392 | 1239 | 1345 | 106 |
| Rabi Sorghum | | | | | |
| Beds (TC) | 734 | 346 | 1080 | 1606 | 526 |
| Flat (TC) | 725 | 242 | 967 | 1352 | 385 |
| Flat (TI) | 541 | 165 | 706 | 1242 | 536 |

TC = Tropicultor

TI = Existing Farm Equipment

Appendix Table A-4.

| | Cropping System | Seed (Rs/ha) | Fertilizer (Rs/ha) | Pesticides (Rs/ha) | Machinery (Rs/ha) | Human and Bullock Labor (Rs/ha) | Total Variable Cost (Rs/ha) | Gross Returns (Rs/ha) |
|---|---|---|---|---|---|---|---|---|
| **Mahbubnagar (Aurepalle)** | | | | | | | | |
| **Alfisols** | | | | | | | | |
| Village watershed | Castor Sole (HYV) | 43.08 | 421.75 | 123.5 | 39.93 | 144.8 | 773 | 1316 |
| Farmer | Castor Sole (Local & HYV Mixed) | 23.32 | 12.5 | 0.85 | - | 302.5 | 339 | 326 |
| Village watershed | Pigeonpea intercrop with Sorghum (HYV) | 54.95 | 410.2 | 110.5 | 35.62 | 163.23 | 775 | 3086 |
| Farmer | Sorghum Mixture (Local) | 13.0 | - | - | - | 235.0 | 248 | 421 |
| **Akola (Kanzara)** | | | | | | | | |
| **Medium Deep Vertisols** | | | | | | | | |
| Village watershed | Sorghum (HYV) | 84.0 | 428.25 | 58.5 | 37.58 | 156.27 | 765 | 1788 |
| Farmer | Sorghum (HYV) | 56.0 | 138.92 | 27.28 | - | 339.5 | 562 | 1425 |
| Village watershed | Pigeonpea intercrop with Sorghum (HYV) | 118.5 | 428.25 | 65.0 | 36.85 | 180.29 | 829 | 2042 |
| Farmer | Cotton Local + Local Sorghum + Pigeonpea Local | 36.10 | 21.65 | 0.82 | - | 709.0 | 768 | 701 |
| **Sholapur (Shirapur)** | | | | | | | | |
| **Deep Vertisols** | | | | | | | | |
| Village watershed | Sorghum Rabi (HYV) | 175 | 351 | 208 | 68.52 | 277.36 | 1080 | 1606 |
| Farmer | Sorghum Rabi (Local) | 12.7 | 1.5 | - | - | 236 | 250 | 396 |
| Village watershed | Pigeonpea (HYV) | 128.0 | 194 | 455.0 | 55.04 | 290.87 | 1123 | 3806 |
| Farmer | Pigeonpea (Local) | 13.34 | - | - | - | 74.15 | 88 | 282 |