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INTEGRATING CROPS AND LIVESTOCK AND LIVESTOCK RESEARCH AT IRRI

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Between 1964 and 1975, farming systems research at IRRI evolved from on-station intercropping experiments, to on-farm multi-disciplinary research on crops/livestock systems. The transition occurred as each introduction of new technology onto farms, and close observation of the results, led to an ever wider identification of the problems of improving rice technology for the Asian rice farmer. The adoption, use and benefit of using improved rice technology depends upon other crops, non-crop farm activities, and affairs of the village, country and levels of community in between. We recognized however that while the environment within which technological changes take place must be understood, our choice of an instrument for bringing change remained all-important. Advances in research and development appeared to require narrowly defined objectives.

Thus while broadening our understanding of the circumstances that impinge on successful intervention in rice-based farming systems, our instrument of change remains rice technology. Our objective is to use rice technology to expand food-producing farm activities. It is accomplished both through our own research, and by providing research services to national institutions. Research services are provided through the Asian Farming Systems Network (AFSN), formerly the Asian Cropping Systems Network (ACSN).

Beginning in 1975 the technical and methodological results of IRRI's cropping system research were shared with similar programs in Asia through the Asian Cropping Systems Network. The ACSN was coordinated by a member of IRRI's cropping systems research program. Network coordination was separated from research in 1983 and established as the "Rice farming Systems Program", one of IRRI's five global research services. It assists governments in establishing farming systems research programs, coordinating training, and facilitates the identification of research problems and communication or research results through field tours, workshops and conferences in the Region. IRRI's own farming systems research continues to be conducted in the "Cropping Systems Research Program".

In the following part of this paper I will briefly describe the Rice Farming Systems Program activities to support national research program on crops-livestock systems. In the second part I will present

results of recent crops-livestock research at IRRI. In the final part of the paper I will suggest possible strategies for the development of crop-livestock systems in Tropical Asia.

SERVICES FOR CROPS-LIVESTOCK RESEARCH

The Asian Farming Systems Network initiated international collaborative research on crop-livestock systems with a workshop in Los Baños, April 25-28, 1983 (Asian farming Systems Network, 1983). One summary session of the workshop set objectives and technical framework for collaborative studies in each of five countries, Nepal, Indonesia, Philippines, Sri Lanka, and Thailand. The objectives of the studies are to improve the quantity and quality of food consumed by farm families, and to increase their income and employment. The research will focus on rice-based farming systems, seeking ways to better utilize the rice plant, introduce feed crops into rice-based cropping patterns, and utilize the by-products of introduced crops.

The second summary session considered methods of research. Performance prediction will be used to screen national livestock technologies to a greater degree than for crop technologies because cost, complexity and time requirements for livestock experiments are greater. Few trials at few locations will be conducted and therefore prospectively a wider range of scientific expertise can be devoted during the period of an experiment. Technical research will largely aim to increase feed supplies and therefore analytical methods developed for cropping systems research can be used.

The Rice Farming Systems Program at IRRI will support the five national crop-livestock research projects with assistance from the Institute of Animal Science of the University of the Philippines. The latter will conduct supportive research on livestock while IRRI conducts crops research that will support the livestock system (Institute of Animal Science, 1983). The objectives of the IRRI-UPLB farming systems support project are as follows:

1. To establish collaborative research on crop-livestock production systems between IRRI and national programs in Asia.

2. To develop and refine crop-livestock research methodologies to be used in the Asian Farming Systems Network.

3. To further develop relevant component technologies for both crops and animal systems.

4. To facilitate exchange of research information and ideas among scientists in asia on crops and animal production systems.

5. To promote collaborative research between crops and animal scientists (Institute of Animal Science, 1983).

Crops-livestock research will be conducted in the five countries at locations where cropping systems research was previously conducted for at least 2 years. Feed crops and other feed-producing techniques will be introduced into cropping patterns. The five sits will serve to develop and refine methods for incorporating livestock in cropping systems research. The models developed will then be extended to other farming systems sites within the country.

The location for Philippine research is in Santa Barbara Municipality, Pangasinan Province, a rainfed wetland rice system, with farms of about 2.2 ha in size. Farmers own an average of 2 head of cattle and water buffalo. IRRI researchers will directly particpate in the Philippine project, conducting research on food crops in rice-based patterns that can be used for both grain and fodder. Farmers presently plant one rice crop, sometimes preceded by corn or followed by mungbean. Varieties of cowpea and mungbeans will be evaluated for both grain and fodder production an introduced into the cropping pattern. Pigeon pea will be introduced after rice as a sole crop or intercropped with mungbean. Leucaena glauca and pigeon pea will be tried in homelots for additional animal feed, (Animal Science Institute, 1983).

The project will involved 15 farmer cooperators and be administered by Ministry of Agriculture, Regional Integrated Agricultural Research (RIAR) team. The Bureau of Animal Husbandry will supply veterinary services and participate in the research activities. It will be the first occasion for IRRI, participant in a multi-disciplinary project, to engage in crops research specifically for the support of livestock activities. Previous IRRI crop-livestock research was aimed solely at assessing the role of livestock in rice-based cropping systems. In the following section of this paper results are presented from some of the on-going research in this area.

ROLE OF LIVESTOCK IN A RICE SYSTEM

When Solana Municipality, Cagayan Province, Philippines, was selected for cropping systems research, high livestock numbers was one of the features that attracted IRRI researchers. Cagayan Province has the largest bovine herd of all provinces in the Philippines, comprising mainly carabao, or water buffalo, and this is reflected in the high density of draft carabao on rice farms. On their average 3-ha holdings, Solana farmers keep two work animals, compared to an average of one or less on other non-mechanized farms in Batangas, Iloilo, and Pangasinan where cropping systems research was previously conducted.

Researchers wanted to understand why Cagayan rice farmers keep more than twice as many work animals as other farmers and how this relates to the cropping system, particularly the potential for improved cropping patterns. Along with studies to identify more productive cropping patterns, practices of carabao raising, marketing and use on farms were also examined. The results are presented below to show the relationship

of draft animal production to cropping systems in Solana, Cagayan, leading to suggestions in final section of specific research that might be conducted at IRRI to support more productive farming systems.

Cagayan Crops and Carabao

Farms in Solana average 3 ha of which half is light, recent alluvial soils adjacent to the Cagayan river where farmers grow mainly corn and mungbeans in seasons when the river is low (Table 1). The upland is regularly inundated for about four months each year when the river rises, however the date of flooding varies by as much as two months and introducing high variability in crop yields. Drought also periodically damages upland crops. Generally farmers attempt to grow two crops a year on the upland, one after rains start in April or May, before the river rises, and another after the river recedes around December.

The other half of farmland comprises heavy soils on the upper river terrace, or talon, where farmers mainly grow rice. Relative elevation of these lowlands declines with distance from the river, and during the rainy season water accumulates to a depth of about one meter. Here farmers grow a single crop of a tall, traditional Javanica rice varieties, but often attempt no crop at all. Shallow rainfed conditions prevail on the higher elevated lowlands and farmers sometime attempt a crop of mungbeans after rain starts, but before sufficient water accumulates for rice. But again, when this will occur varies over several months and leaves uncertain each year whether it is better to try mungbeans first or to proceed with rice. The entire lowland is subject to flash floods, lasting a week on the higher portions and three weeks on the lowest part. Also, prolonged dry periods often occur after rains commence, damaging mungbeans if early, or rice later.

Floods or drought often delay or damage crops. Crop histories recalled by farmers suggest that in two out of three years, half or more of a crop's yield is lost to drought or flood. Indeed during the three years of IRRI's research at Solana, floods severely damaged farmers rice crops in 1980 and 1983, and also in 1982, drought caused additional damage. One of the three pre-monsoon crops planted on the upland was destroyed by floods, and all three of the post-monsoon upland crops were damaged by drought.

Figure 1 shows the farmers' cropping patterns and IRRI's experimental patterns that were tried in the first year of research, in relation to average rainfall in the area (Gonzaga, et. al., 1982). The main emphasis of research is finding ways to increase cropping intensity, possibly by using early maturing rice varieties and direct seeding techniques to enable harvest of an early HYV rice crop before floods. A second crop might then be planted. Simply stabilizing the system so that fewer losses are incurred is also an objective. Higher yet profitable rates of variable inputs are employed on the experimental

patterns but play a secondary role in researchers attempts to improve crop production and incomes.

A survey of cropping practices when research began in early 1980 showed that modern rice varieties were not in use, almost no fertilizer was applied, and no herbicides or insecticides. The situation has changed somewhat over the last three years with many farmers trying modern rice varieties, and using some of other inputs. Table 2 is a summary of crop management from 1980 to 1983, showing low levels of cash inputs. (As presented these results bear few implications concerning the impact of unfinished cropping systems research because until now there have been no attempts to introduce new cropping practices.)

Carabao management in Solana

Carabao provide traction power to farms according to the schedule shown in Table 3. The time required for various operations are shown in Table 4, adding up to a total work time per year of about 740 hours per farm, or 390 hours per carabao. Most (78%) of traction power is provided by farmers' own animals, 20% by animals hired (with their handlers) from other farms, and 2% by animals hired with workers from landless households. Table 5 shows the work capacity of carabao by age and sex compared to usual work hours on days when they are in use (Acebedo and Church, 1982). While farmers gave the estimates of work capacity shown, they caution that animals should only occasionally work such long hours. Daily work at their maximum capacity would lead to sickness.

The value of a work carabao in 1980 was 1620 pesos ($216), giving a total value of 4240 pesos ($565) for the average 2.14 animals owned per farmer. Farms monitored during the three year study were stratified into four groups by size, but over this range the number of carabao did not vary (Table 6). The average farmer possessed about 7910 pesos ($1055) worth of capital items used with carabao including upland and lowland plows, harrows, cart sled and harness (Gonzaga, et. al, 1982). A plowman with carabao was paid about 15 pesos ($2.00) for a day's work, twice the payment when a plowman is hired alone to work with an owned carabao.

The average Solana farm also has swine and poultry worth about 350 pesos ($47). Sales of livestock averaged 608 pesos in 1980-81 ($81), compared to 737 pesos ($98) for crop sales. Livestock sales accounted for 43% of cash income from farm household. Cash expenses for livestock activities were 78 pesos ($10), 22% of farm cash expenses and 2% of total cash expenses of the farm household (Gonzaga, et. al, 1982). Livestock clearly play an important role in the cash liquidity of the farm household, of which carabao sales are a component. In 1982, 4 (15%) of 26 working animals that researchers began monitoring in January were sold, and one of them was subsequently replaced by offspring and one replacement was purchased. After on-farm reproduction, the most

common method of acquiring carabao is to care for other farmers' animals, and in return receive the offspring. Another method is simply to rent a work animal for the crop season and pay one-quarter of the rice harvest after paying harvest costs. Other farmers use animals that have simply been loaned or given by relatives.

Sixty-seven percent of the Solana carabao herd comprises animals of working age, 7 to 20 years old, 58% of which are castrated males. The adult females produce 0.51 calves per year but no attempt is made to control breeding. Males are castrated at age 4 and females produce their first calves at age 5 (Acebedo and Church, 1982). Higher rates of reproduction are not attempted, farmers say, because it would be difficult to feed more animals. The rate of natural mortality in 1982 was 0.4% of the working herd. The majority of working animals are vaccinated every year, for an overall annual vaccination rate of 83% of the adult herd.

While providing needed traction power to farmers, and enhancing the cash flow, carabao require high labor inputs for feed procurement. In 1982, an average of 3410 hours per farm were spent caring for carabao or about 4.4 hours per day per animal, 35% by male farm household heads (Table 7). With relatively large farms and a highly variable crop schedule, farmland lies fallow much of the time. Grazing animals on fallow lowland and upland accounts for 70% of the labor used in livestock care in Solana. The upland can be used in March, and any unflooded parts in August through October. Open lowland can be found in most other months except October or December, when crops or deep water cover the landscape. Twenty-four percent of annual labor for carabao care is spent at this time herding animals on the hillsides, which requires the operator, a son or other male relative to live at remote campsites for several weeks. Another 6% of annual labor for livestock care is spent cutting grass for animals, concentrated mainly in these same peak months of the rice cropping season (Table 8).

Relationships of corps and carabao

Analysis of crop and carabao production and management in Solana suggest several interrelationships that strongly influence the performance of the two subsystems. Because of sizeable and varied land resources and a highly uncertain climatic environment, a larger-than-usual draft power capacity is an economic necessity. Soil and weather conditions favor crop establishment at highly dispersed, brief and unpredictable periods of time. Farmers must be prepared to act quickly to sow or transplant crops, and this can only be done if ample traction power is available. This is reflected in quick one-week sequences of plowing and planting on many small plots, compared to the more usual pattern in other locales of first preparing large contiguous areas for simultaneous planting. The unpredictability of appropriate planting dates is seen in rice seedlings that may age from 20 to 80 days in nurseries waiting for acceptable soil and weather conditions.

The value to farmers of traction power during critical periods of land preparation is indicated by the wage rates they pay. Five-week moving average wage rates are shown in Figure 2 computed from hiring transactions observed among the 48 farmers whose activities were monitored in 1980-81. Compensation in kind as well as in cash is included in the computation. When rains first came in April 1980, land preparation for corn on the upland and for mungbeans on the lowland both required large amounts of draft power adn pushed up hiring rates. Costs per hour fell and rose thereafter when soil and weather conditions became right for subsequent crops.

The same conditions that require a high draft power capacity also provide the means to procure it. Land and weather conditions cause large areas to remain fallow during much of the year, supplying forage to animals. Otherwise farmers would likely have mechanized their farms by now. With relatively cheap feed supplies, it has remained profitable to use animal draft power. Low labor wage rates in remote and unindustrialized Cagayan Province have also played a role; cheap herding labor has been necessary for the system to survive. In fact rising wage rates might well lead to the eventual decline of the system.

Feed supplies and cropping patterns, particularly improved cropping patterns, are linked more closely than might appear. If mungbeans are to be grown on the lowlands before rice it is critical that they be planted soon after the rains start because if their growing period extends too late into the rainy season they will die from water-logging. Despite this problem, widely recognized by farmers, still mungbeans are delayed until corn on the upland is established. As a consequence, lowlands that might have been planted to mungbeans are left idle. An improved early mungbean crop was a major emphasis of cropping systems researchers, expecting to increase cropping intensity by increasing the area of this crop.

It is now clear that the improvement will not be possible (Gonzaga, et.al.). Although profitable, the improved crops of mungbeans grown by researchers were not as profitable as corn grown on the upland. Further, traction power is only sufficient to plant corn and mungbeans one at a time, resulting in a characteristically late, flood-prone mungbean crop. The profit that could be made from growing a timely mungbean crop is not sufficient to induce farmers to add to their draft animal capacity, particularly when faced with already strained feed supplies. The draft capacity of present carabao numbers is apparently just sufficient to operate at present levels of cropping intensity. So far, higher cropping intensity does not appear profitable enough to pay farmers to keep an additional carabao through the year.

The principal interactions of crops, carabao and climate in Solana can be summarized as follows:

Highly variable climate means that favorable times for land preparation and planting are dispersed and brief, hence requiring a high traction power capacity on farms.

The climate situation causes land often to lie fallow, which in turn supports large numbers of carabao to supply draft requirements.

Carabao numbers are limited to present levels by available feed, chiefly cut grass and forage.

Using traditional planting methods, area planted is limited to present levels by land preparation capacity of the draft animal herd.

New technology to grow crops in periods when draft power is unused, or to grow crops with minimum tillage, may help to increase cropping intensity, but may reduce forage needed by draft animals, and hence result in a yet lower capacity to prepare land for crops.

Improved technology for producing feedstuffs may permit an increase in both carabao and cropping intensity.

RESEARCH STRATEGIES, SOLANA AND BEYOND

The situation in Solana, Cagayan, leaves IRRI researchers with a choice among several alternatives. At past research sites an approach was followed much like the work at Solana to date. That is, new cropping patterns were developed that were suited to the current levels of draft power supply, and other farm resources. Livestock numbers were monitored but no technical intervention into the livestock subsystem was attempted. Incidentally, in Iloilo where previous cropping systems research was conducted, the new cropping patterns were widely adopted and cropping intensity increased such that wage rates, including that for land preparation, increased sharply. Mechanization of harvesting ensued, and later, of land preparation also.

Despite the analysis that was conducted on livestock and other subsystems of the farm, because only crop technology was directly manipulated, the work has been regarded as cropping systems research. Another approach is to seek technical change in both the crop and non-crop subsystems of the farm, in which case the work might be termed "mixed systems" or "farming systems" research (Price and Tait, 1981). Further, the changes may be technically related or unrelated. The former is closer to farm management research than to systems research because the principal objective is to develop and/or introduce activities that more advantageously share the farm resource base. The

innovated activities are technically unrelated in the sense that the innovation of one does not necessarily imply changes in the productivity of resources in the other activity.

In a second type of technological change, the innovated activities in two or more subsystems of the farm are so related that innovating one activity necessarily brings about a change in the productivity of resources employed in the other (See Henderson and Quandt, page 67, for a discussion of technical relationships in production, and Lee, page 204, for an application to multiple cropping). An example is changing to a corn insecticide that is not toxic to animals, making it possible to use the stover as feed.

In Solana some general choices are:

Continue to design and test only crop technology (e.g. improved rice-rice patterns.

Design and test technically unrelated crop and livestock technology that support more draft animals (e.g. on some land grow grass for cutting and feeding, and other land grow an improved mungbean-rice pattern).

Design and test technically related crop and livestock technology that supports more draft carabao (e.g. grow a grain legume before rice the residue of which can be fed to livestock).

Decision criteria

The proposition of new research at IRRI should be considered with respect to the following conditions:

The research objectives fit within IRRI's mandate to improve nutrition and incomes in rice growing areas through improved quality and quantity of rice (IRRI, 1982, p. 4);

Suitable human and other resources are available or conducting the prospective research, and

Prospective gains for the research are greater than those expected for alternate expenditures.

The first condition is interpreted to include rice research that raises food production generally, without regard to the quantity of rice specifically. Hence, in cropping systems research new rice technology is developed and employed that helps improve the production of either or both, rice and non-rice crops. This is the context in which the direct seeding of early maturing rice varieties was first proposed by cropping systems researchers, a technique that might sacrifice rice yield, but enable planting an additional crop of either rice or an upland crop.

Research opportunities to increase food production on rice farms independently of the rice technology employed, are generally regarded to lie outside the mandate. A test for whether a prospective technology for producing a non-rice crop, or non-crop activity, sufficiently relates to rice production was described earlier. That is, if the technology is used, would the productivity of resources employed in rice production be affected?

The above guideline has been carefully followed in the cropping systems programs at IRRI, where research on non-rice crops has always played an important role. Much of the work focuses on rice and non-rice crop sequences in which the management of all the crops in the sequence are strongly interdependent. There have been opportunities to conduct research to improve non-rice and non-crop enterprises on the same farms where rice is grown. However when the technical relationships with rice is not clear, the work has been avoided or suggested to other agencies. At the IRRI-CIADP cropping systems research site in Solana, research to improve crops grown on the upland is conducted by the Cagayan Integrated Agricultural Project (CIADP), while IRRI's efforts focus on the lowland where rice is grown.

The reason for limiting the scope of cropping systems research to rice-related technologist is not merely the consequence of the perceived mandate of IRRI, for that at times has been open to reinterpretation. (For example, any work on non-rice crops would seem to be precluded by the stated purpose of improving nutrition and incomes through improved quality and quantity of rice.) A narrow research focus also follows from the second criteria for choosing research, suggesting that suitable human and other resources should be available for conducting the prospective research. IRRI's human and physical resources have been acquired and developed for rice research,and cannot easily support agricultural research unrelated to rice production. Where non-rice expertise has been needed for rice-related research, the gap is filled by ancillary projects funded and conducted outside the Institute. For example, a grain legume breeding project at the Philippine Plant Breeding Institute was designed and funded to support IRRI's cropping systems research.

Finally, prospective research to solve multi-enterprise problems in the farming system of Solana, or elsewhere in IRRI's rice-based farming systems program, should be considered in view of the relative gains from research. This is related in part to the previous criterion, since IRRI has a substantial research infrastructure devoted to rice, prospective gains from rice-related technologies will be less costly than those from other areas of agricultural research, if conducted at IRRI. The other question is, given that some further expansion of research into rice-related, non-rice enterprises is appropriate, which among the other farm subsystems are likely to offer the greatest gains from IRRI's new research investment.

The schematic representation of a farm in the cropping systems on-farm methodology (Zandstra, 1982) suggests at least two other subsectors that might offer high returns to rice related research (Figure 3). The farm household consumes rice and produces labor. It is very clear in Solana, for example, that nutrition is an over-riding concern of farm household particularly when crops have been damaged by floods or drought. Crop loss in 1981 so strongly affected the physical and mental health of villagers in Solana that research was virtually halted with several "cooperating" farmers. The design and testing of technology with respect to nutritional requirements of the household should be considered against alternate new directions in research.

The petty merchandising, handicraft, off-farm employment and marketing activities of households also strongly interact with the rice subsector, earning cash for inputs and transforming crop produce into cash for the family needs. Improvement of farm human capital through training and improvement of extension services is yet another innovation, strongly interactive with rice production, which can be brought about through research on extension and other forms of technology dissemination and acquisition.

Biological subsystems of the farm that in certain locales are more important than livestock include aquaculture and agro-forestry. Rice production on a significant minority of Asian farms is technically related to forest-based enterprises. The design and testing of new rice technology for regimes in which forest land is a major resource could favorably affect the livelihoods of approximately 0.5 million "kaingineros," or "slash and burn cultivators," (Fernandez, 1983) in the Philippines alone, while alleviating some of the systems' destructive effects on land and water in both the highlands and lowlands. These as well as the non-biological subsystems of the farm might be considered along with livestock as possible new subjects of rice-related research.

In summary, it follows from IRRI's mandate, the resources available at IRRI, and rates of possible gains per unit of research cost, that any expansion of agricultural systems research to non-crop enterprises be directed toward the development of technologies that bear strong technical relations to rice. An approach to solving problems affecting the carabao-rice production systems in Solana should be considered in this light.

Research on Rice-bovine Systems

Maintaining a passive research approach to bovine production in the rice-based system in Tuguegarao remains an attractive alternative. Certain advances are being made toward increasing the rice cropping intensity using minimum tillage techniques and early maturing of submergence tolerant rice varieties. These are attractive to farmers and entail the employment by IRRI of no new areas of expertise. The livestock sector will be affected; likely carabao numbers would decline

as the land is increasingly covered with crops and the feed supply becomes restricted. Mechanization of land preparation, with machine services paid for by new crop surpluses, is also likely. Exogenous development of the Cagayan Region is likely to increase wage rates which in turn will bring further pressure on the carabao industry as herding costs increase.

But these are a lot of "ifs," and still nothing can be done about the weather. An alternative approach is to incorporate increased animal feed supplies into the farming system, and here there are several choices, as follows:

Purchase feed for carabao

Produce forage or other feed outside the rice-based cropping patterns

Produce forage or other feed within rice-based cropping patterns.

The first two alternatives should be rejected because although they may be profitable, they imply research that is not technically related to rice. It is not appropriate research for IRRI. The last alternative, producing feeds in rice-based cropping patterns in turn suggests the following additional choices.

Use of rice straw

Production of grasses before or after rice

Growing non-rice crops with a feed-quality residue in sequence with rice

Growing non-rice feedgrains in a rice sequence

Growing a feedgrain quality rice

Growing a dual purpose rice variety, that can first be used for forage or a fresh grass feed, and that later can produce grain for human consumption.

Rice straw is not a high quality feed and furthermore farmers already exploit this feed source to the extent that it is profitable. The growing season is so restricted by weather that establishing a grass crop before or after rice is likely to bear a higher opportunity cost than can possibly be paid from additional livestock carrying capacity. Grain legume hay is a possibility, but experimental crops produce only marginally profitable grain crops, and insignificant amounts of hay. Furthermore, while research to better manage grain legumes in sequence with rice can be justified as "rice-related", research to improve grain legumes with respect to their technical relations with both rice and

livestock is a complex proposition as a whole within farm innovation. It implies substantial simultaneous technology development and extension in several far enterprises, including perhaps an entirely new activity in on-farm feed processing. Hence it is unlikely to meet with quick success. More will be said of this later.

Although low-grade rice is used for brewing and fed to livestock in other countries, especially Thailand, it is seldom used for working bovine herds. In Solana it is not a likely approach to supporting carabao herds. However, should a feed quality rice variety be developed that yields better than varieties for human consumption it would likely offer benefits to swine and poultry raisers while increasing returns to rice producers. Production of a feed quality rice would offer benefits to rice producers particularly when prices for the grain for human consumption are low, as presently. Feeding of low quality wheat to livestock has traditionally provided a floor under wheat prices in wheat growing countries, and with appropriate breeding, the same could be done for rice.

Use of green vegetative parts of the rice plant, either fresh by grazing or cutting and feeding, or as silage, possibly offers a quicker and higher return to IRRI research than any other livestock technology related to rice. Table 9 shows the nitrogen content of rice leaves at different periods after planting. A long maturing rice plant might offer several crops of fresh grass feed before entering the reproductive adn ripening stages. Farmers in Ilocos and the Cagayan Valley in fact traditionally prune their wagwag rice varieties, taking about half the plant, and feeding it to their animals. In Bandarawela, Sri Lanka, farmers prune the entire plant to about 15 centimeters to prevent damage during the windy part of the growing season.

Recognizing that the carabao feed supply is lowest in Cagayan when the rice crop is in the reproductive and ripening stages, possibly a silage process might be employed for saving surplus vegetation for feeding at this time. Dairy farmers in Central Luzon pay farmers 0.15 pesos/kg for green corn fodder (with immature ears) which they make into silage for feeding milk cows.

Grazing of short-statured, long maturing rice varieties before the reproductive period may be possible while the crop is grown on firm soil, before flooding. Or such a plant type grown as an upland rice might be grazed. Rye and oats are managed in this manner in temperate climates. Ratoon rice crops are already a component of the post-rice feed supply that might be improved through rice breeding. However in most rice growing areas, the post rice-period is the least critical period of bovine feed supply (Price, 1973).

The possibilities suggest new initiatives in rice breeding and experimentation in management of the rice crop. The possibility of breeding a high-yielding feed-quality rice grain should be investigated. Breeding and screening of rice varieties for ratooning ability should be increased, and the grazing potential of short-statured varieties should be investigated. The possibility of harvesting one or more fresh grass or silage crops from medium or tall rice varieties before the crop enters reproduction should be studied, perhaps by mowing various selections in the vegetative period. The nutritive value of green vegetative parts of the rice plant should be analyzed, along with that of silage produced through alternate processes.

Use of the rice plant itself as animal feed would seem to lie within IRRI's mandate and area of expertise. If research on livestock in rice-based farming systems is deemed to have sufficient payoff to merit IRRI's attention, obviously this particular approach to technology development should be considered. In fact, given the remoteness from IRRI's mandate and expertise of other possible innovations to support livestock in rice-based farming systems, there can be little justification for IRRI's conduct of farming systems research.

Exploiting markets for the crop-livestock linkages

The advantages of developing technology for crop livestock systems are based upon the proposition that gains from their direct technical linkage on small farms substantially outweigh prospective gains from developing either independently, and linking them through markets. Linking feed and livestock production through markets obviously incurs costs for the marketing function. But these costs may be outweighed by the value of efficiencies from producing what grows most profitably on the land, and feeding to animals the most profitable rations. Experimental crop-livestock technologies should be compared against this standard.

I cannot presently offer a rigorous analysis, but I suspect that small farmers' and researchers' resources would be better spent developing crop and livestock enterprises independently than on some of the notional technologies I have presented above. In recent years, large-scale animal enterprises have flourished in Asia, keeping the cost of animal protein in diets much lower than what it otherwise would be. These industries often are based on imported feed supplies. In the Philippines, soybean meal imports have risen dramatically since the mid-970's (Table 10), to nearly 250 thousand metric tons in 1983 (Price and Paris, 1983). With a recent devaluation of Philippine currency and attempts to control food prices, livestock producers are in jeopardy. Research to support feed production for local markets may prove a more beneficial use of research funds than the investment we are making in on-farm technical linkages of crops and livestock.

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Table

Farm
1.00
1.01
2.01
3.01
4.01
5.01
Aver

Table 1. Landholdings of farmer respondents in Solana, Cagayan, 1979.

Farm size group (ha)	Farmers (no.)	Parcels (no.)	Area (ha)		
			Lowland	Upland	Total
1.00 or less	12	1.5	0.64	0.17	0.81
1.01 - 2.00	20	2.6	0.92	0.74	1.66
2.01 - 3.00	25	3.0	1.56	1.02	2.58
3.01 - 4.00	20	4.0	2.09	1.53	3.62
4.01 - 5.00	15	4.9	2.17	2.44	4.50
5.01 or more	8	5.9	3.55	3.29	6.64
Average	-	3.7	1.66	1.34	3.00

Table 2. Costs and returns ($/ha) of 87 farmers' plots planted to the mungbean-transplanted rice (TPR) pattern on First Stratum lowland, Solana, Cagayan, 1980 - 1983.

	Mungbeans	TPR	Total
		($)	
Value of labor	17	85	102
Value of draft power	6	20	26
Material cost	10	10	20
Total variable cost	33	115	148
Yield (kg/ha)	29	1030	-
Gross returns	19	188	207
Net returns	-14	73	59

Table 3. Average work time per carabao by month and operation. Solana, Cagayan, Philippines, 1982 (hours).

Month	Clear	Plow	Harrow	Furrow	Hilling-up	Hauling	Total
January	0.0	6.1	1.3	1.4	3.5	2.2	14.5
February	0.0	1.3	0	0	0.4	1.0	2.7
March	1.0	5.7	0.3	0	0	1.4	8.4
April	0.9	35.7	3.4	9.7	0	1.7	51.4
May	0.0	2.1	0.8	3.0	1.8	0.4	13.1
June	0.1	10.3	4.5	2.1	5.4	0.4	22.8
July	1.1	8.5	1.3	0.2	0	0.5	11.6
August	7.2	26.8	9.4	1.3	1.3	1.1	47.1
September	9.3	18.6	17.4	.4	0	0	45.7
October	9.9	30.6	16.8	0.0	0	0	57.3
November	13.4	27.3	11.1	3.4	0	5.3	60.5
December	9.2	22.6	4.1	6.6	6.5	3.7	52.7
Year	52.1	200.6	70.4	28.1	18.9	17.7	387.8

Table 4. Comparison of animal power requirement (hrs/ha)

Pattern	ACTIVITIES					TOTAL	
	Plowing	Harrowing	Furrowing	Cultivation	Transport	Crop	Pattern
Traditional lowland patterns:							
Mung/Rice (TPR)	48/85	27/64	103/0	0	0/7	178/156	334
Fallow/Rice (TPR)	0/92	64	-	-	0/7	0/156	156
Traditional upland patterns:							
Corn/Corn	54/80	13/16	25/22	24/72	6/6	122/196	318
Corn/Mung	56/74	19/20	30/21	30/11	6/0	141/126	267
Designed Cropping Pattern:							
TPR/Mung	80/22	74/10	0/13	-	7/0	161/ 45	206
TPR/TPR	74/41	70/42	-	-	7/7	151/ 90	241
Mung/DSR	51/75	24/77	24/52	-	0/7	99/211	310
Mung/TPR	35/67	15/54	17/0	-	0/7	67/128	195
Mung/DSR/Mung	41/28/0	29/24/0	15/15/25	-	0/7/0	85/74/25	184
Mung/TPR/TPR	41/43/35	15/37/30	14/0/0	-	0/7/7	70/87/72	229

Note: The data above are for the crop year 1980-81 when the crops were exposed to floods and drought. Therefore, the reader should be cautioned that the animal power requirement may be understated, further field research will be conducted to obtain more reliable figures.

For designed patterns no carabao transport figures were available; it is assumed therefore that transport requirements will be at least as much as for traditional crops.

Source: Acebedo and Church, 1981.

Table 5. Potential and actual work capacity of carabao.

Age (years)	Potential hours/day		Actual hours/day		Actual as % of potential	
	Male	Female	Male	Female	Male	Female
3-6	9	8	6	4	66.6	50.5
7-12	11	11	8	7	72.7	63.6
13-20	10	10	7	6	70.0	60.0

Table 6. Average number and value of livestock by farm size, Solana, Cagayan, 1980.

(Values in pesos)

	0.50-1.25		1.75-2.50		3.00-3.75		4.25-5.00	
	No	Value	No	Value	No	Value	No	Value
Carabao	2	1330	2	1609	2	1801	2	1621
Swine	2	181	2	233	2	261	2	373
Poultry	7	7	11	9	8	9	10	8

* Value per head

Source: Gonzaga, et. al. 1982.

Table 7. Time spent caring for draft water buffalo on Solana farms, Tuguegarao, Philippines, 1982.

Source	Hours/year/farm[a]	Hours/day/animal[b]	% Total
Farmer	1199	1.54	35
Wife	39	0.05	1
Son	645	0.83	19
Daughter	448	0.57	13
Other	1079	1.38	32
Total	3410	4.37	100

[a] Eleven farmers kept daily records of livestock operations, supervised by IRRI Cropping Systems researchers.

[b] Sample farmers owned 26 draft water buffalo in January 1, 1982, declining to 21 by January 1, 1983. Four animals were sold and one died, for an average weekly inventory of 2.14 working carabao per farm.

Table 8. Source of feed, % total intake per month by source, Solana, Cagayan, 1981.

	Mountain forage	Cropland forage	Cut grass
January	0	85	15
February	0	99	1
March	0	99	1
April	0	96	4
May	0	98	2
June	0	90	10
July	0	95	5
August	0	98	2
September	0	100	0
October	58	40	2
November	87	5	8
December	78	6	16
Year	24	70	6

Table 9. Percent of nitrogen content of rice tops by weeks after transplanting after incorporating preceding crop residues. Suphanburi Experiment Station, Thailand, Wet Season, 1977.

Cropping pattern	% nitrogen content in rice tops by week after transplanting			
	1	3	5	10
R	3.2	3.3	1.8	1.0
S-R	2.8	2.7	1.8	1.1
Mg-R	3.1	3.2	1.7	1.1
Mz-R	2.6	2.6	1.9	1.1
Mg-S-R	3.2	3.3	1.9	1.2
P-S-R	3.5	3.3	2.3	1.2
Mz-S-R	3.2	3.2	2.0	1.2

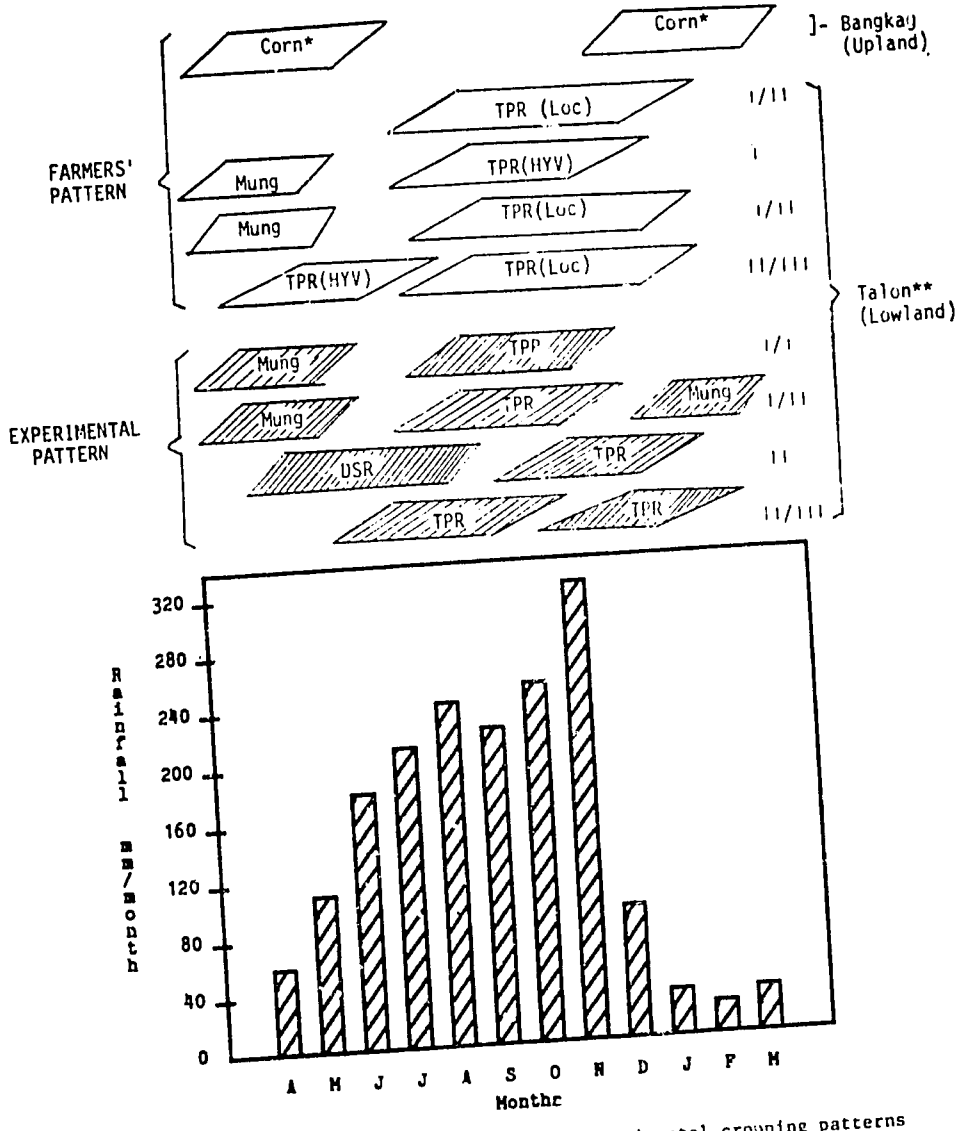

Fig. 1. Farmers' traditional and IRRI experimental cropping patterns for 1981-82 graphed against 25-year average monthly rainfall for Solana, Cagayan. (Source: Adopted from Gines and Morris, 1981).

*Mungbean and cowpea are occasionally substituted for or intercropped with corn.
**Number refers to IRRI classification of talon areas.

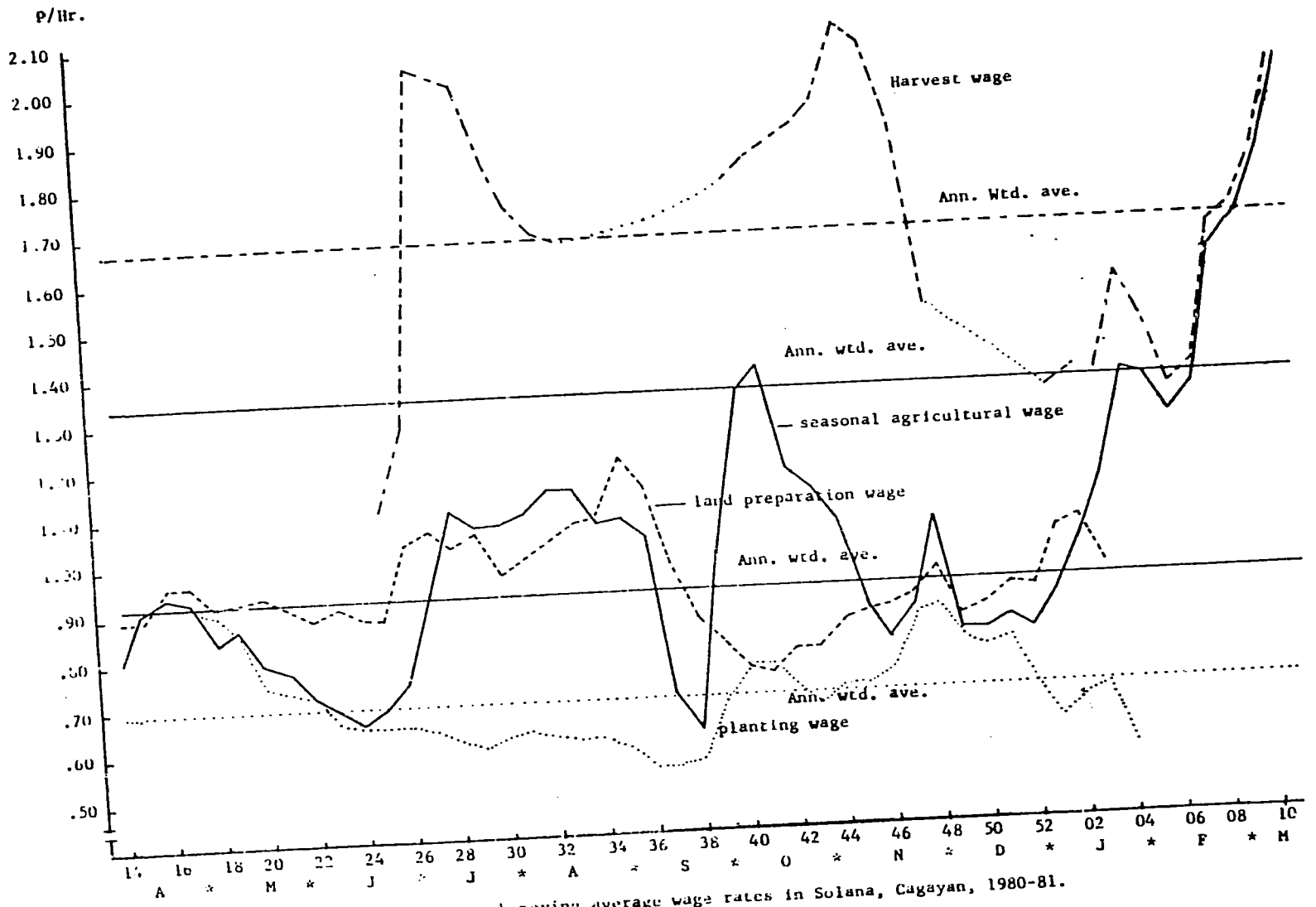

Fig. 2. Five-week moving average wage rates in Solana, Cagayan, 1980-81.

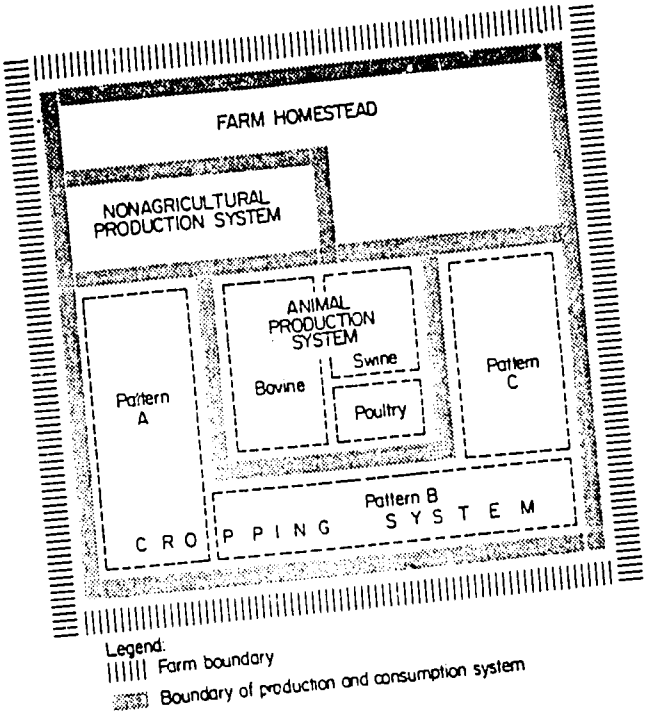

Fig. 3 Schematic presentation of small-family farm household system with 4 production-consumption systems.