Results from Nepal's cropping systems research program are raising the productivity of some of the world's smallest landholdings.
"It is time that we call upon the scientist, agriculturists, and technologists to operationalize their talents, their capabilities, their skills so that they can be helpful to the masses of Nepal, so that they can be helpful to the farmers of Nepal. I also call upon other sectors to realize that, if they are to seriously participate in national development, they will have to work with the agricultural sector, because the agricultural sector will have to be accepted as a "lead" sector for some time to come."—Mohan Man Sainju
Most farmers in Pumdi Bhumdi, a mountain village in western Nepal, are glad when their maize yields 3000 kilograms a hectare. But recently several dozen farmers took part in a pilot maize production program and achieved average yields of 6000 kilograms a hectare. This remarkable increase resulted from the application of an innovative scientific approach called cropping systems research.

To launch the production program, a government agronomist helped the Pumdi Bhumdi farmers organize production blocks—groups of adjoining fields that would be managed identically. After the pre-monsoon rains soaked the terraced fields, they plowed in their usual way and sowed Khumal Yellow, a new maize variety. In addition to their customary practice of dumping a few baskets of compost on each field, they broadcast some chemical fertilizer. They followed the agronomist's advice on guarding against destructive insects and on hoeing out weeds periodically during the growing season. None of these practices were unknown to the farmers. But putting them all together along with an improved variety—one that richly rewards good management—was a technological leap for most farmers and led to the startling results.

The small farmer

For the typical villager, call him Kancha, and his family, an important consideration in agreeing to take part in the production program is that the cropping pattern (12-month sequence of crops) in the fields devoted to the program would remain unchanged. Researchers of the Department of Agriculture classify those fields as “upland, high production potential.” Kancha's family tills a little under a hectare of land, and, of that, the “upland, high production potential” land constitutes less than 10 percent.

The best land is intensively cultivated. The family members sow maize, the main crop, in March. In July, a month before the maize is harvested, they transplant finger-millet seedlings among the maize plants. The gain of several weeks by “relaying” the millet crop into the maize crop permits Kancha's family to harvest the millet in early November, leaving a few days for them to plow the land and sow wheat. The wheat crop is then harvested in March, just in time to plant the maize crop once again.

Because of the tight scheduling imposed by this cropping pattern, Kancha's decision to try new techniques hinged on more than just the hope of higher maize yields. He had to assess, in addition, the effect that adopting the recommended variety and management practices might have on the crops that follow maize in the cropping pattern.

Furthermore, Kancha's concern was not limited to that individual cropping pattern. The family's land is in six scattered pieces and
The planting period is short and draft power is scarce: a farmer sows maize behind the plow, without additional tillage, to save time. On them five distinct cropping patterns (see sidebar "Farming systems terminology") are employed:

- 0.06 ha. maize/millet-wheat
- 0.07 ha. maize/millet-fallow
- 0.11 ha. rice-wheat-maize
- 0.13 ha. rice-wheat-fallow
- 0.23 ha. rice-fallow-fallow
- 0.20 ha. rice-fallow-fallow

Harvest, land preparation, and planting—the periods of intense field work—tend to fall at different times in these cropping patterns. If new methods would force the peak labor period for one pattern to shift, it might conflict with the family's ability to furnish sufficient labor at critical times in other patterns, with potentially disastrous effects on their precarious food supply. Thus Kancha's cropping system—the cropping patterns taken together—stagger and spread the periods of heaviest labor needs.

The full range of farming activities—Kancha's farming system—embraces more than just crops. A water buffalo and its calf, several goats, and a few chickens are vital sources of cash income and occasionally enliven the family diet with meat and dairy products. Bullocks provide draft power. The dung produced by the animals, mixed with crop residues, leaves, and other vegetative matter becomes compost, which is the family's chief means of maintaining the fertility of their fields. The livestock have to be tended daily: Gathering forage, watering the animals, collecting dung, and other husbandry activities occupy three fourths of the family's farming labor.

The ability of the new maize variety, Khumal Yellow, to fit this delicately balanced farming system is not accidental. Khumal Yellow is one of a number of maize varieties that cropping systems researchers tested in Pumdi Bhumdi as part of several cropping patterns including maize/millet-wheat. These on-farm trials showed that Khumal Yellow could substitute for the local variety and that, in combination with some improved production practices, it could give farmers like Kancha exceptional returns.

A research chain

The maize varieties in the tests at Pumdi Bhumdi had been developed at the national maize station at Rampur. Cropping systems
researchers draw on the national research programs in maize, rice, wheat, and other crops for new varieties and new techniques to test at Pumdi Bhumdi and other cropping systems research sites throughout the Kingdom. Thus the arrival of Khumal Yellow in Kancha's field is the culmination of a chain of experimentation and adaptive testing designed to mesh new technology with the exacting requirements of the cropping systems used by small farmers.

The elaborate agrarian tapestry that is Nepalese agriculture presents a stern challenge to researchers' skills. The scientist's ideas and inventions may be successful in isolation, but they have little value if they do not fit the prevailing farming systems. The farmer's methods on the other hand may be ancient or seem overcautious, but they are the product of a reckoning that integrates all the resources, risks, and requirements that exist within the farmer's span of vision. And they work—they have kept the farm family alive from one generation to the next.

That is not to say that it is futile for scientists to attempt to help farmers—far from it. Scientists can draw on a vast array of materials and a body of knowledge that are not within the village farmer's grasp. Moreover, the scientist has skills in finding ways to combine new techniques and materials for maximum effect. The key is to view the world through farmers' eyes in order to spot improvements that will fit farmers' systems. That is the crux of cropping systems research.

Learning from farmers

Cropping systems research is a means of finding out what farmers do and why they do it, and systematically applying that knowledge to test solutions to farmers' problems. In Nepal it is not uncommon for two fields lying side by side to be cropped quite differently, one with a high-value crop intensively managed and the other with a minor crop haphazardly managed. The fields may be similar in topography, drainage, and soil quality. Their owners may be equally industrious. The explanation for the differences may lie far from the fields themselves, in decisions their owners have to make about managing other fields, about allocating family labor, about borrowing draft animals, about risk, and so forth.

Cropping systems researchers take knowledge about farmers and their practices and put it to work in testing improved varieties, seeding rates, fertilizer application methods, and other ideas in farmers' fields and prevalent cropping patterns. Technological ideas that pay off with little disruption of existing systems are most likely to be rapidly adopted and to have a far-reaching impact on agriculture.

Thus cropping systems research is the middle ground between experiment station research and production campaigns. Cropping systems research filters and refines the broader research conducted under controlled experiment station conditions. Cropping systems trials test not only the technological worth of new ideas, but also their compatibility with the economic and social circumstances of farmers.

Experiment station research, cropping systems research, and production programs are interdependent parts of the productive agricultural research and development system.
"Food problems are sensitive both from political and social points of view. In remote hill areas of the country, direct government involvement may be needed for both political and social reasons. At the same time, the government is often faced with inherently contradicting interests of providing higher prices to the farmers while at the same time maintaining the supply of food grain at lower prices to consumers."—B.B. Khadka and J.C. Gautam

Food shortages

Paradoxically, despite undernutrition in many districts, Nepal has been a grain exporter in some years. The explanation traces to the three major ecological zones into which the country is divided.

The majority of the 16 million Nepalis live in the Hill region, the Himalayan "foothills" ranging from 300 to 3000 meters in elevation. The arable land of the Hills is cultivated as intensively as any land on earth.

Less than half of the population live in the Terai, the steamy plains bordering India, which are dissected by tributaries of the great Ganges river. Until after World War II, the jungle-covered Terai was more hospitable to tigers and rhinoceros than to man. As malaria was suppressed, settlers started to chop back the jungle in order to cultivate the region's alluvial soils. Now the Terai harvests about two-thirds of the Kingdom's cereals.

The Mountain region ranges in elevation from 3000 meters to 8800 meters (the peak of Sagarmatha, or Mt. Everest) and is lightly populated. Perpetual snow covers much of it. Herding is the chief agricultural activity.

In the Hills, the rugged terrain hinders the movement of food and other commodities. The first road linking the capital, Kathmandu, to the Terai and the outside world opened in 1952. As recently as 1976, only 15 of the 55 districts in the Hills could be reached by road.

Where the roads end, goods are shifted to the backs of porters. Trains of porters, each man bearing 60- or 70-kilogram loads, trek for days or weeks to bring goods to remote villages. So universal is trekking that distances are commonly measured in days of walking rather than in kilometers.

The high cost and sheer difficulty of transporting bulky products keep food supplies from moving freely from the surplus-producing area, the Terai, to the deficit area, the Hills. Equally important, the Hill region is more impoverished than the Terai. Thus even though the road network is growing, the flow of food supplies is unlikely to enlarge greatly unless the people of the Hills can expand their purchasing capacity.

In the past, the Terai produced a surplus of about 300,000 tons of grain a year, while the Hill region had a deficit of 100,000 tons a year. Government agencies purchased about
Farmers and researchers visit a variety trial at a high-elevation site.
The fields are small, but the harvest is good.

"The development and dissemination of yield-increasing agricultural technology are often regarded as the key mechanisms in boosting agricultural output. The successful utilization of such technology depends on a strong programme of adaptive research and a comprehensive extension programme designed to diffuse this technology which must, to begin with, be appropriate and suitable for adoption by the farmer. Research into what constitutes appropriate technology i.e., therefore, of vital importance. Agricultural research must be problem-oriented and research results must be tested under farmers' conditions."—T.N. Pant and G.B. Thapa

40,000 tons of grain annually to sell at subsidized prices in the Hills. In 1982, a poor year, government food distribution in the Hills exceeded 100,000 tons. Less than 10 of the 55 Hill districts had a surplus.

Population growth is straining the capacity of the Hills. The slopes are being deforested as people gather wood for fuel, fodder for livestock, and vegetative matter for compost. Erosion is causing landslides and floods.

Agricultural productivity has been declining for more than a decade. In the 1970’s, according to an analysis by B.B. Khadka and J.C. Gautam, cereal production in the Hills rose by 1.27 percent per year, but the area planted expanded by 1.66 percent, implying that yields fell 0.5 percent per year. For maize, the most important crop in the Hills, the situation is worse—output has dropped even though the area planted to maize has expanded. Now the consumption of staple foodstuffs by an average person in the Hills is nine tenths that of his countrymen in the Terai.

**Changing food policy**

In government councils, the food crisis commands increasing attention. Government expenditures on agriculture quadrupled (in real terms) during the 1970’s. Planned expenditures on agriculture will double during the first half of the 1980’s. Agriculture in the Hills however is only beginning to get the emphasis its importance warrants.

From the 1960’s through the early 1970’s, public expenditures were focused on the Terai, which was seen to have a greater development potential. Programs involving subsidized inputs, the development of agricultural institutions, and irrigation hardly affected the Hills, and extension work was minimal.

In the Fifth Five-Year Plan (ending 1980), attention turned to the agricultural development of the entire country, and, in the Sixth Five-Year Plan, the stress is on food production in the Hills. The changed priorities come none too soon. Economists project that within a generation the grain deficit of the Hills will be 1.5 million tons a year, barring a radical change in agricultural productivity trends. The maturation of Nepal’s cropping systems research program gives hope that a significant and sustainable rise in agricultural output can be achieved.
A little compost is the only means most farmers have for renewing soil fertility.

Food stocks are kept close at hand.

Sinuous terraces and a multiplicity of crops reveal the intensity of Nepalese farming.
The cropping systems approach

The cropping systems project of Nepal’s Department of Agriculture has two broad objectives: to improve the technology (varieties and methods) that farmers use in their cropping systems, and to help spread proven technology rapidly.

One way farmers can produce more is by realizing higher yields from crops they already grow. Consequently, the cropping systems project tests new varieties and methods within existing patterns. Another way is to grow more crops each season. Thus researchers are seeking practical ways to insert an additional crop in existing cropping patterns.

Cropping systems researchers in Nepal pay attention to all economic activities of farmers including animal husbandry, and they are directly concerned with the role of compost and the importance of feed supplies in influencing the choices farmers make about their cropping systems. The program might be called farming systems research except that so far no specific research on farm animals has been undertaken.

Representative research sites

Cropping systems research in Nepal is done at six primary locations. The sites were chosen to be representative of major agro-ecological situations of the Kingdom, so that ideas proven successful would have the widest possible applicability. Four sites are in the Hill region, one is in the Terai, and one is in the Inner Terai, a vast, flat valley separated from the Terai by a range of hills. The sites differ in length of rainy season (from 2 to 6 months), type of soil (three major soil groups are involved), and size of farm (the site averages range from 0.5 ha. to 1.1 ha.). Farmers at all sites grow rainfed lowland rice. But at some sites, farmers also grow rice with irrigation, and at one site some upland rice is grown, too.

When the sites were initially chosen, social scientists of the cropping systems program made surveys to draw a quick socio-economic profile of each one. These surveys were done by finding a dozen or so knowledgeable villagers (key informants) at each site and conducting intensive interviews. Subsequently, more elaborate surveys involving randomly selected farmers, crop cutting, and direct observation were conducted to provide additional information.

Surveys are one tool in the continuing socio-economic analysis that is necessary for cropping systems research. Some of the findings from Kancha’s village, or panchayat, Pumdi Bhumdi, convey the rich detail that the key-informant surveys provide:

- Farms average three fourths of a hectare each. Farmers believe one farm in three is too small to support a household.
- Hail is a threat particularly at the beginning and end of winter though it doesn’t occur every year. Damage can be severe.
About half the land lies fallow in winter. Insufficient compost and the difficulty of protecting far-off fields from marauding monkeys and untethered livestock are the main reasons.

Little produce is sold.

Labor shortages occur during land preparation, transplanting, and harvest of rice.

Bullock shortage is an important cause of poor land preparation.

Feed shortage during the winter limits the number of animals farmers can keep, and hence the amount of draft power available and the amount of dung produced.

“Agricultural inputs such as fertilizer and improved seed are the only substitutes for the limited land in the Hills. Thus planners in Nepal have to supply more inputs and complementary services to Hill farmers. The provision of food to the Hills is a short-term solution while the supply of agricultural inputs is a long-term one.”—R.B. Singh and G.R. Shrestha

Surveys of farmers provide detailed information that guides cropping systems research activities.

A member of the Planning Commission, M. Sainju, right, goes to the field to see new wheat production practices and to question farmers and scientists.
Most farmers keep a female water buffalo to derive cash income from its milk and offspring.

- Milking buffalo and working bullocks are fed some grain—usually millet, as well as roughage.
- Low soil fertility is a major barrier to more intensive cropping and higher yields. The lack of sufficient dung, inefficient compost-making practices, the scarcity of legumes in the village's cropping systems, and the slight amounts of chemical fertilizer applied all contribute to the problem.

Research staffing

Nepal's cropping systems research staff consists of 2 agronomists, 10 assistant agronomists, and 2 social scientists. Because of shortage of funds and qualified personnel, the program usually operates with one or more vacancies. The cropping systems program is part of the Integrated Cereals Project of the Department of Agriculture. ICP, which is partially supported by the U.S. Agency for International Development, aims at improving all aspects of cereal research and production. Three of the foreign resident specialists assigned to ICP work primarily with the cropping systems program.

In addition, at each cropping systems site, a technician assigned by the Department of Agriculture serves as the coordinator. The site coordinator lives in the village and gets to know farmers' problems and aspirations. He and two or three aides recruit farmers as cooperators, see that trials are properly installed, and collect yield data and other information. Enterprising site coordinators are the backbone of cropping systems research in Nepal.

There is little difficulty in finding farmer-cooperators. Most trials involve crops the farmers would grow anyway. And the seed and fertilizer the researchers supply for the trial reduce the expenses the cooperators would otherwise have. When the season is over, the full harvest is the farmer's.

Cropping patterns

To establish research priorities, cropping systems researchers have to understand farmers' existing practices. Through interviews and observation, researchers learn how farmers categorize their various parcels of land and what cropping patterns predominate in each land category.

Kancha and his neighbors in Pumdi Bhumdi distinguish between upland and lowland fields (see "Farming systems terminology") and subdivide those two types into high production potential and low production potential. Production potential is related to the amount of compost that the parcel receives and the soil's capacity for holding moisture. Fields with low production potential are usually planted only once a year, while those with high production potential tend to be double-cropped or triple-cropped.

The predominant cropping patterns in Pumdi Bhumdi are:

- Upland, low production potential
  - maize/millet-fallow
  - maize/millet-mustard

- Upland, high production potential
  - maize/millet-wheat
  - maize/millet-potato
Lowland, low production potential
rice-fallow-fallow

Lowland, high production potential
rice-wheat-fallow
rice-fallow-maize
rice-wheat-maize

To study farmers' cropping patterns, the cropping systems workers sample and weigh the inputs that cooperating farmers use. For seed, for example, the data collected provides information on the variety planted, the germination rate, and the seeding rate. The workers also record when and how thoroughly each cooperating farmer carries out cultural practices such as land preparation and weeding. And at harvest time they measure yields. From this information, costs and income can be calculated.

Some operators may be asked to alter their regular practices somewhat. Without changing the customary cropping pattern, a farmer might be asked to use a different seeding rate, to apply a dose of chemical fertilizer, to plant a new variety, or to try combinations of these or other new ideas. This line of research is aimed at improving farmers' existing practices.

Researchers also investigate ways to intensify cropping patterns by growing a crop when land is ordinarily in fallow. For example, rice-fallow-fallow might be changed to rice-fallow-maize. The main technical problem would be to find a maize variety that could be planted in early spring and that would mature fast enough to permit on-time planting of the main crop, rice.

A third line of cropping pattern research involves intensification by introducing alternative crops. In Pumdi Bhumdi, for example, researchers have tested cropping patterns that include such crops as lentils, peanuts, broadbeans, soybeans, mungbeans, or oats. Some of these are already grown as minor crops in gardens, in patches of wasteland, on extra steep slopes, in mixtures with maize, or on the bunds of rice paddies. But finding practical ways to fit them into major cropping patterns could boost productivity and incomes substantially.

Experiment station research is the beginning of a long chain of testing that culminates in farmers' fields.
Nepal's Food: Production of the Three Major Cereal Crops
("Hills" = Hill region + Mountain region)

Most of the people live in the Hills
Population 1980 (millions)

Most cereal is grown in the Terai plains
Cereal output, 1981 (000 tons)

Rice, the largest crop, is grown mainly in the Terai
Cereal output, 1981 (000 tons)

Production gains in the Hills have been small
Cereal output, (000 tons)

Wheat, the smallest of the three crops, has been a large contributor to higher production
Output change: 1981 vs 1968 (000 tons)

Wheat growing has expanded rapidly
Change in area, 1981 vs 1968

Cereal yields have tended to fall
Average yield, '70's (kg/ha)

And per capita production has fallen
Cereal output, 1979 vs 1959 (kg/person)
Component research

The varieties introduced and practices being tested in cropping pattern research are ones that have shown promise in component research. Component research is also done by enlisting the cooperation of farmers. But instead of planting one rice variety, the farmer might be asked to subdivide his field and plant six varieties next to one another. In such side-by-side plantings, researchers and farmers can compare new varieties. How vulnerable are they to local insects and diseases? How fast do they ripen? How well do they tolerate dry spells? Answers under site conditions to such questions permit selection of the most suitable variety for introduction into cropping pattern testing.

Similarly, comparative trials of fertilizer are made. Does application of phosphorus, or potassium, or some minor element improve yields? What rate of application is most economic for maize? for rice? in low potential soils? in high potential soils?

Or what about seeding rate or time of planting? The number of questions that can be investigated in component research is limited only by funds and the researcher's good sense about trials that are likely to have a high payoff.

In practice, because component testing involves a small number of variables, the trials can be superimposed on cropping pattern testing. That is, component testing can be conducted without disturbing existing cropping patterns. In fact it is important that component comparisons be made within the context of cropping patterns because of the far-reaching impact one change can have on the rest of the cropping pattern. Fertilizer, for example, often affects not only the crop to which it is applied but the following crop as well. A realistic assessment of the optimum rate of fertilizer has to embrace the effects on the entire cropping pattern.

Farmers' role in trials

Cropping systems research melds the farmer's unique understanding of local farming conditions with the researcher's insights about technological options and knowledge of reliable methods for testing choices quickly. Every year about 400 farmers take part in research at the six cropping systems sites.
Farmers collectively guide the research. In initial key-informant surveys, information from farmers influences the types of trials that are established. Continuing surveys provide additional data on farmers' risk perception, off-farm employment, division of labor, and other subjects that can have significant bearing on the practicality of new technology and hence the priorities for experimentation. The farmers manage the trials; they harvest and consume the produce. Researchers seek farmers' opinions about the trials conducted in their fields and in their neighbors' fields. Comments that a variety is too late, too short, too difficult to thresh, or that a cultural practice takes too much time become part of the information that the researcher weighs in planning subsequent trials. Farmers are also asked what should be studied. Oats, for example, are being tested at Pumdi Bhumi because farmers said they are interested in the crop as a livestock feed. Finally, the continual observation that occurs when the scientist is regularly visiting a farming community becomes a means of reinforcing or moderating ideas formed in talking with farmers.
Social and economic analysis

In cropping systems research, no sharp line divides agronomic and economic research. The agronomist must recognize the social constraints and economic limitations that farmers face. The social scientist must know the biological, chemical, and physical basis of farming. The difference between the two types of scientists is mainly in the focus of their interests.

The agronomist and the social scientist work side by side. The principal activities of

---

**FARMING SYSTEMS TERMINOLOGY**

*Symbols*

Croppings systems researchers use certain symbols to indicate the relation and sequence of crops in a cropping pattern:

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Meaning</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>-</td>
<td>followed by</td>
<td>rice-wheat</td>
</tr>
<tr>
<td>+</td>
<td>mixed with</td>
<td>maize + soybeans</td>
</tr>
<tr>
<td>/</td>
<td>relay</td>
<td>maize/millet</td>
</tr>
</tbody>
</table>

Thus the cropping pattern “rice-wheat-fallow” means that in a 12-month period a rice crop is followed by a wheat crop, which is followed by a fallow period. The pattern repeats itself every 12 months. “Rice-wheat-maize” means rice is followed by wheat, which is followed by maize. The first crop listed is the main crop—the crop that is planted at the beginning of the true rainy season.

**Definitions**

cropping pattern. The yearly sequence and spatial arrangement of crops within a field.

cropping system. The various cropping patterns used on a farm and their interaction with each other and with other farming activities.

farming system. Activities related to cropping and livestock production on one farm.

intercropping. Two or more crops planted together.

relaying. Planting one crop among the maturing plants of a previously planted crop.

lowland fields. Fields that are flooded for rice growing during at least part of the year. Lowland fields usually have bunds to trap and retain water. Even if some other crop, such as wheat for example, follows flooded rice, the field is still considered lowland. The term has little to do with topography: On the same hillside, lowland fields may be higher on the slope than some upland fields.

upland fields. Fields that are not submerged during any portion of the cropping season.
Reading recommendations from cropping systems researchers.
the social scientist are developing agro-climatic and socio-economic profiles of the cropping systems sites, elaborating understanding of farming systems employed at the sites, helping establish priorities among cropping systems trials, gathering information from farmers about the trials, comparing the returns and risks of new technology and old technology, and helping to formulate recommendations to be used in production campaigns.

All results from cropping systems research are ultimately measured in economic terms. Researchers look for improvements that lead to high net returns, but that also have reasonable cost so that the technology is within the economic reach of small farmers.

**Difficulties In conducting research**

Farmers' fields are not easy places to do research. Textbook experimenters despise uncontrolled variables, and at cropping systems sites, few extraneous variables can be controlled.

A host of factors frustrate the researcher's desire for "normal" and uniform testing conditions. The fields in which cropping systems researchers place trials often vary in fertility or water-holding capacity. Individual test plots are likely to differ in size and shape because the terraced hillside fields in which they are placed rarely are neat rectangles.

Furthermore, farmers who agree to cooperate do not always provide wholly typical conditions. They are more likely to designate a poor field for research than one of their better fields. They may also change the way they care for the trial field by, for example, applying less compost than usual or leaving weeding until all their other fields are weeded. And, sometimes, farmers unexpectedly harvest the trial field before the site coordinator can sample it to measure yields—and the season's research results are lost.

Trials designed to find ways to intensify cropping systems are especially vulnerable to unusual destruction. Such trials tend to be out of step with normal cropping practices because they are planted earlier or later than neighboring fields, or when other fields are fallow. Sometimes trials involve crops different from those in surrounding fields. As a conspicuous island of growing vegetative matter, such trials exert a powerful attraction for birds, monkeys, and insects, not to speak of wandering farm animals. Yet, if a proven technology developed from out-of-phase trials were adopted by numerous farmers in a locality, pests would remain dispersed and farmers would have an incentive to control their livestock, so the damage might be less intense.

**Many happy returns**

Despite these pitfalls, cropping systems researchers are amassing a wealth of information on existing and improved cropping systems and putting it to use. A sampling of some of the improvements coming from cropping systems research in the Hills:

- At Pumdi Bhumdi, a new rice variety, K39, and a new maize variety, Arun, have set the stage for sharp increases in the output of lowland soils where rice-wheat-maize is the major pattern. K39 fits as the main season crop and yields more than any local rice variety. Arun, because it is early maturing, can be planted following wheat when the first spring showers occur, yet it can be harvested by the time the full-fledged monsoon rains start, so that rice can be planted without delay. In lowland fields in Pumdi Bhumdi, where the traditional pattern is rice-fallow-fallow, planting fast-growing Arun...
maize just before rice (rice-fallow-maize) can more than double food output. In upland fields where maize/millet-wheat is grown, replacing the local variety of maize with Khumal Yellow greatly improves yields. Better practices also raise yields of the millet and wheat without any change of variety.

- At Chauri Jahari, a dry area of western Nepal, the usual pattern in lowland fields is rice-wheat-fallow, with the wheat grown in the winter with irrigation. An improved rice variety, Laxmi, plus improved practices for both rice and wheat raises yields substantially. In upland fields where rice + maize-wheat + mustard-fallow is popular for high-production potential soils, Arun maize performs well interplanted with the upland rice. Improved practices for wheat, which is grown with irrigation, have a substantial yield effect. In addition, substituting mungbean, a quick-growing legume crop, for the fallow period following wheat provides extra returns from this pattern.

- Rice-wheat-fallow is also the common pattern for lowland fields at Lele in central Nepal. Farmers have been planting T176, an improved rice variety, for several years. But by introducing pure seed stocks and better management ideas, cropping-systems researchers have been able to help farmers increase yields.

- At Khandbari, for rainfed lowland fields, rice-linseed-fallow, rice-fallow-maize, rice-fallow-mungbean, and rice-mustard-fallow can advantageously be substituted for the traditional rice-fallow-fallow. In upland fields, Khumal Yellow maize has made a great impact in the traditional pattern maize-millet-fallow and in maize-maize-fallow with Arun as the second maize crop.

The improved and alternative cropping patterns all require the farmer to apply more inputs, or employ more labor, or use more draft power. The cost may be modest, 20 or 30 percent more, or it may be double or triple what the farmer is already investing in crop production. The return on the improved technology, however, makes the investment worthwhile. Benefit-cost analysis shows that with good weather the farmer may get back 8 or 10 rupees for every additional rupee invested in improved crop production, and occasionally the returns go to 12 or 13 to 1. In poor years, the returns fall off to 2 or 3 to 1, yet are still enough to cover the higher cost of improved technology.

Tieing in the research stations

Some kinds of research are impractical except under research station conditions: crossing plants and selecting progeny, screening thousands of varieties and lines for insect resistance or disease resistance, or conducting experiments to determine the interaction of several agronomic practices. In addition an important activity of national experiment stations is the testing of experimental varieties and methods developed in other countries and by international research institutes.

The central stations for research on the major cereals of Nepal are all in the Terai and Inner Terai. However, in recent years commodity research has become more dispersed.
The national rice program, for example, now does varietal development work at 1500 meters' elevation near Kathmandu and has a testing location at 2000 meters' elevation, in addition to its main station in the Terai. As a result of increasing experimentation at higher altitudes, several new varieties have been released that are well-suited to the temperate climate of the Hills.

Throughout the year, commodity researchers and the cropping systems researchers meet informally during frequent visits to experiment station plots and cropping systems sites. At the annual summer and winter workshops, the cropping systems researchers and the commodity researchers review new findings and plan future experiments.

Through this process, the cropping systems researchers get access to promising new lines and methods as soon as the commodity programs have identified them. The strengths and weaknesses of the varieties are promptly reported to the commodity researchers, who use the information in subsequent experimental work.

The development of the maize variety Arun exemplifies the interaction between cropping systems researchers and commodity researchers. Cropping systems research uncovered the urgent need for an early maturing maize variety. Traditional maize varieties were so slow growing that many farmers were forced to harvest the maize while immature to be able to seed the subsequent crop on time. The equally unattractive alternative, which some farmers chose was to harvest the maize at maturity, but to skimp on land preparation for the following crop and to plant it late.

Researchers at the national maize station in Rampur, in the Inner Terai, began selecting for earliness and yield in several maize populations. Promising selections were tested in farmers' fields by the maize program and at cropping systems sites. From this process Arun emerged. The maize population from which it is derived stems from a cross made at CIM-
MYT, in Mexico, between a Philippine variety and a French hybrid. Thus Arun embodies national and international collaboration, which produces rich payoffs from agricultural research.

**Verification trials**

Cropping systems research in Nepal has reached the stage where it has findings worth spreading. Dissemination takes place in two steps: pre-production verification trials followed by production campaigns. At cropping systems sites, however, verification trials are unnecessary so pilot production programs have been started.

Verification trials are intended to make sure that the right recommendation is used in the right place. In the various development districts, the agricultural development officer and extension workers categorize villages (panchayats) in relation to the agro-climatic characteristics of the various cropping systems sites. Panchayats that appear to be similar to one of the sites are tentatively selected and then quickly surveyed using techniques and questionnaires developed by cropping systems researchers. From survey data on the physical environment, on present cropping practices, and on socio-economic conditions, improved cropping patterns can be chosen that are likely to be profitable to farmers. The survey also provides information necessary to spot atypical farmers when selecting cooperators and to avoid unrepresentative parcels of land in choosing fields for the trials.

To help extension workers, the cropping systems staff has written a comprehensive manual called *Guidelines for Pre-production Verification Trials of Cropping Systems Recommendations*. It gives recommendations for 31 improved cropping patterns that have been proven at the cropping systems sites. The patterns are grouped according to the ecological conditions they best fit.

For each crop in each pattern, the manual supplies recommendations for:

- variety
- land preparation
- seed rate
- fertilizer rate
- fertilizer application
- compost use
- planting method
- planting date
- weed control
- insect and disease control
- irrigation
- data to collect

Nevertheless whenever farmers' existing practices for a particular category are sufficient, the manual simply suggests using "farmer's level."

The manual recommends verification trials of up to four improved cropping patterns. Each cropping pattern requires five farmers, each of whom plants about one-tenth hectare of the trial. To provide a basis for comparing the results, about 10 percent of each farmer's trial land is reserved for cultivation with traditional practices.

It may take two years of trials to detect and eliminate patterns that are excessively sensitive to normal fluctuations in seasonal weather in the area. The outstanding cropping patterns in...
the verification trials can then be used as the basis for building production campaigns.

An important role of the verification trials is to introduce cropping systems concepts to both extension workers and farmers. The verification trials encourage extension workers to change their perspective from a crop-by-crop approach to a cropping pattern approach. It also acquaints them with cropping systems recommendations.

The manual for verification trials furnishes practical advice on laying out trials. It recommends that the trial parcels not be excessively scattered, so that the extension worker can easily visit them. It also recommends trial plots no smaller than 500 square meters, because large plots make a more powerful impression on neighboring farmers, are more suitable for field days, and are better seed-multiplication plots.

Field days are integral to the verification trials. They expose farmers in the area to the new technology, they give extension workers an opportunity to get farmers' reactions and to answer questions, and they provide the occasion for farmers to buy or barter for improved seed.

The small cropping systems staff has only limited ability to participate in verification trials. The staff aids the Agricultural Development Offices by training extension workers, providing technical advice, and helping to
Regular meetings of commodity, disciplinary and cropping-systems researchers

Cropping systems research in Nepal
analyze data from surveys and trials. The cropping systems staff also works closely with rural area development projects, which are specifically staffed and organized to operate production campaigns. Several such projects are conducting verification trials preparatory to launching production campaigns using cropping systems technology. The cropping systems staff helps the projects through training and by giving advice on organizing trials.

Production campaigns

The ultimate objective of production campaigns is to increase farm production by introducing improved farming technology. But the initial goal, which will determine the long-run success of production campaigns, is to convince farmers, extension personnel, and, especially, decision makers that the cropping systems approach works. Getting agencies and individuals to work in harmony to raise production throughout Nepal will require strong commitment from politicians and administrators. If the campaigns have their backing, improvements in extension staffing and incentives, in timeliness of input deliveries, and availability of credit will be possible.

Pilot production programs have been launched at the cropping systems sites. The programs are intended as models of ways to raise production. They involve the Agricultural Development Office, the Agricultural Development Bank, the Agriculture Inputs Corporation, the Sajha (cooperatives), and other support agencies of the government. In 1983, pilot production programs at the sites covered 13,000 hectares and by 1985 over 50,000 hectares will be under the programs. Experience gained in the pilot production programs will be used in launching production campaigns in other areas following verification trials.

The central feature of the production campaign is the production block. A block is made up of about 100 hectares of contiguous fields that have the same cropping pattern. Forming blocks allows the production team to work within a small area, so team members can meet frequently with all farmers in the block to resolve problems. One hundred hectares planted to improved varieties and grown with better methods also makes an impressive demonstration, which fosters interest in the production campaign among farmers in the vicinity.
The production team consists of a production officer (for up to 1000 hectares), two junior technical assistants (up to 500 hectares apiece), and one production leader in each block. The production leaders are farmers who have been selected for their influence with other farmers as well as for their interest in the new technology.

After being given training in the technology and in motivating farmers, the production leaders are responsible for persuading their neighbors to organize a production block. They explain the purposes and benefits of the program, how to join, and when to attend meetings. After the block is formed, they help participating farmers apply the new methods. As compensation, production leaders receive a training allowance and, each season, sufficient inputs such as seed and fertilizer for a half hectare of production.

The production team helps farmers follow the recommended practices so that they achieve the full measure of benefits and are thereby encouraged to stick with the new methods. Those who need credit to purchase fertilizer, seeds, or other inputs are given production loans for the whole year, that is, for an entire cropping pattern. The production team makes sure the inputs are on hand locally when the farmers need them.

The production team reaches farmers by seeking them out at the tea shop, rice mill, milk collection station, or other places where they congregate. There, meetings are announced and news of current problems and their solutions can be spread. The production

A sack of improved seed is the prize for the three farmers who achieve the highest yields in a wheat production program.
team also visits farmers' homes 5 days a week to be available to advise on production practices throughout the season.

Monthly meetings are held to discuss topics critical to the success of the recommended technology, such as time of seeding, procedures for processing loans, or rat control. To encourage farmers to attend, a small prize such as a kilo of improved seed or a hand tool may be raffled at the meetings. Meetings are held in the fields, too. Nearby farmers might be invited to visit a production block to see how the new varieties and methods perform. The farmers, it is hoped, will then be eager to form a production block themselves. At another type of field meeting, farmers in the block might gather on the land of the production leader to see operational techniques demonstrated. And, of course, field days are routinely held shortly before harvest to show the results to area farmers, workers in support agencies, and officials.

Pilot production programs began at the cropping systems research sites in 1981/82. At Lele, in central Nepal, for example, yields from production blocks involving a rice-wheat-fallow cropping pattern were 4300 kilograms of rice per hectare and 4400 kilograms of wheat per hectare. These yields were over 60 percent higher than the yields of neighboring farmers. The rice production program at Lele covered 55 hectares and involved 313 farmers, indicating both the small size of the individual fields and the magnitude of the organizing task the production teams face.

**Will farmers adopt the new ideas?**

The production campaigns are organized to deal with the scarcity of inputs, which is perhaps the most formidable barrier to the introduction of new farm technology. In each pilot production program, several farmers are offered the opportunity to be seed growers. They are given advice on growing crops for seed and on methods of processing, storing, and treating seed. Thus each production program has several local sources of high-germination, improved seed in addition to seed available through farmer-to-farmer distribution and outlets of the Agriculture Inputs Corporation.

To improve credit availability, the Agricultural Development Bank has modified its procedures to fit the cropping systems approach. The bank allows participating farmers to borrow against crop production, instead of being required to submit a land registration certificate as collateral. Moreover the loan is made for the whole year, so that the farmer is not obliged to visit the bank each season to arrange credit for the next planting. The junior technical assistants of the production teams help farmers plan a budget for the whole year's operations.

To ensure that inputs are available, the production team gives the local cooperative an estimate of the program's input needs 3 months before each season begins. For instance, one 100-hectare wheat production program in Lele required 20,000 kilograms of 20-20-0 fertilizer, 8900 kilograms of urea fertilizer, and 7500 kilograms of new seed of improved varieties.

"Before we can ask farmers to change, and that is what development is about, there must be other changes prior to changes by farmers—in research, in extension, and in administration."—A.N. Rana and Wayne H. Freeman
"While migration during the last two centuries was characterized by many positive features, the recent movement of people from the Hills to the Tarai brought about a number of socio-economic repercussions. The drain on the hill labor force, ecological imbalance and the declining hill economy on the one hand, and encroachment of forest land, resettlement problems and the negative impact on the Tarai economy on the other become critical issues for Nepal, and they are looming larger everyday."—M.M. Sainju and Ram B.K.C.

**USAID ASSISTANCE TO THE CROPPING SYSTEMS PROGRAM**

In the early 1970's Nepalese government officials and representatives of the U.S. Agency for International Development began planning the Integrated Cereals Project. Their aim was to strengthen research on cereals and the cropping systems in which they are grown and to ensure that the technology that results could be readily adopted by the average farmer. Although the project was concerned with the whole country, the planners were particularly interested in improving the agricultural productivity of the Hill region. The cropping systems program of the Department of Agriculture was seen as the focal point for identifying useful new technology and for furnishing well-tested, reliable varieties and practices to farmers through the extension system.

Since 1976, with funds made available by USAID, Nepal has improved facilities at national commodity research stations, provided local and foreign training for several hundred researchers, and contracted with the International Agricultural Development Service (IADS), Arlington, Virginia, USA, for technical assistance and services. Agricultural specialists provided by IADS have helped to institute a multidisciplinary approach to commodity research and to launch the cropping systems program. As the Integrated Cereals Project has progressed and as Nepalese scientists have returned from advanced studies, the number of foreign specialists has been reduced and assignments have been shifted to new areas. IADS staff members are no longer working directly with the commodity research stations. More of the IADS staff time is being devoted to helping organize on-farm trials and production campaigns and to training production teams.

The planners of the Integrated Cereals Project set out to bring about significant institutional changes in the way that research is done and in which it reaches farmers. The progress that has been made is testimony to the soundness of the planners' vision and the willingness of authorities both in the government of Nepal and USAID to make a long-term commitment to the project.
Training programs are under way to acquaint extension personnel with the cropping systems approach and recommendations. Training takes place mostly in the field, just as does the instruction they will be giving to farmers.

Women are being employed as field assistants to improve contacts with women farmers, who constitute half the farm labor force of Nepal. Tasks such as seeding and the cultivation of certain crops such as millet are almost exclusively done by women. Moreover, most other field operations, aside from land preparation, are shared by men and women. Because there are few female agricultural extension workers in Nepal, some village women who are high-school or primary graduates have been recruited for training.

Will the farmers adopt new technology? In Nepal, as elsewhere, it seems likely that they will, provided that the technology is a genuine improvement over their existing methods and that they can get the seed and other inputs that are needed.

Certainly innovations have swept the Kingdom before. In 1965 short wheat varieties that had been bred in Mexico were introduced to Nepal from India. The Mexican wheats were faster maturing and had more disease resistance than local varieties. Many Nepalese farmers found that in some fields previously left fallow during winter they could plant the new wheats and have them harvested in time to plant maize or rice. Within 4 years, the wheat area doubled; and within 10 years, it tripled. Now almost 400,000 hectares of wheat...
"Sustained growth and development in agriculture is possible only when scientists, technologists, and farmers work together to solve a problem or improve the existing situation. A farmer is an uneducated scientist and economist, but he is the accomplished judge for any technology made available to him. His rejection or adoption of any technology makes a whole lot of difference to the time, effort, and money put in the development of technology."—B.B. Khadka

An abundant crop is the product of good farmers, good varieties, good practices, and good science.

are grown, 85 percent in improved varieties. At about the same time, several short, fertilizer-responsive varieties of rice from Taiwan were introduced. The varieties were suited to temperate conditions and, for farmers with irrigated fields in the fertile Kathmandu valley, the potentially high yields of the Taiwanese varieties made it worthwhile to switch. Even a major drawback of the Taiwanese varieties—that they are harder to thresh than local varieties—did not prevent their adoption. Farmers soon adopted foot-operated thresher like those used in Taiwan.
Expanded production campaigns

By 1985, when 50,000 hectares are scheduled to be under pilot production programs, enough agricultural development officers will have been trained to enable production campaigns to be launched throughout any district for which there is suitable cropping pattern technology. Procedures for making credit readily available to farmers will have been proven and modifications in the system for providing inputs will help ensure that they reach farmers on time.

Cropping systems technology is not difficult for farmers to adopt. Unlike the purchase of a new piece of equipment, it does not require a large investment, and farmers can easily revert to customary practices if the new technology does not work out.

Surveys made by social scientists prior to launching production programs have shown that farmers generally have heard of the improved varieties and are willing to use chemical fertilizer, even if they have not done so before. Some farmers, in fact, start using components of the new technology before production programs begin. The surveys have also shown that farmers desire some production credit, but they are willing to participate in production programs without it.

On the other hand, the surveys have revealed several farmer attitudes that will slow the rate of adoption. Farmers do not perceive great advantages in the new varieties and practices. Furthermore, their understanding is often incomplete. They may know about improved varieties, but not about the practices that are recommended with a new variety. Women are particularly likely to be uninformed because the extension service is not in contact with them.

Success in convincing farmers to try new methods will breed new problems. As more farmers adopt new technology on more land, demand for credit will swell enormously. The volume of inputs that will have to be delivered on time will be immense. Difficulties in marketing will arise as district consumption requirements are exceeded by local production. Policy makers will have to address new problems of prices and transportation of agricultural commodities. Nevertheless, struggling with surpluses would be a welcome change after decades of dealing with shortages.

A better future

As long as the densely populated Hill region is a food-deficit area, the paramount priority of researchers must be raising the production of cereals, the staple foods. But when farmers in the Hills become better able to ensure the basic dietary needs of their families, they will seek to expand more profitable enterprises. As a temperate agricultural zone on the edge of the Asian tropics, the Hill region has an immense comparative advantage for the production of horticultural crops and dairy products if marketing systems can be developed. Large-scale production of fruits, vegetables, spices, milk, and cheese could give the Hills a sound basis for commerce, not only with the Terai plains, but with Asian subcontinent as a whole.

Cropping systems researchers are placing increasing emphasis on improving soil fertility, which is the critical factor in permitting the transformation of the Hill region from subsistence agriculture to an efficient commercial agriculture. Immediate gains in output can be achieved through greater use of chemical fertilizer, but in view of the vast area involved and the mammoth logistic problems, fertilizer is not likely to be the whole solution. Researchers are looking at ways of applying fertilizer more efficiently so that more of it is used by plants and less is volatilized or washed away. Opportunities exist for improving farmers' compost-making methods so that more of the nutrients are retained. Mixing chemical fertilizer and compost can enhance the nutritive value of both products. Cropping systems researchers are also investigating legumes that might fit certain cropping patterns, particularly in fallow periods. Legumes improve the fertility of the soil, especially if plowed in as "green manure," and they make excellent feed for livestock. Other crops, such as oats, and certain trees, offer possibilities as livestock feed. Cropping patterns involving them are being studied.

Even as cropping systems researchers shift their sights, some of the testing of varieties and methods can be transferred to the production programs themselves. Thus by using the production team to take on some of the necessary continuing research, the cropping systems researchers can turn their attention to new challenges. —STEVEN A. BRETH