1 INTRODUCTION
Stanford Cazier

2 INTERNATIONAL PROGRAMS AT USU (1915-1981)
N. Keith Roberts
USU’s commitment to helping less affluent peoples help themselves began in 1915. Over the years, that commitment has led to increasingly diversified but consistently useful work.

6 WHO BENEFITS FROM INTERNATIONAL PROGRAMS?
E. Boyd Wennegren
Altruism has a noble sound to it, but practical considerations often keep us from embracing the philosophy. Economical data, however, prove that when we go to less developed countries to fight world hunger, we gain measurable benefits for ourselves.

10 DEVELOPMENT ECONOMICS
N. Keith Roberts and Morris D. Whitaker
Valid, long-range cost/benefit analyses are basic to agricultural planning. USU economists have produced notable effects on less developed countries by both doing the analytical work and training their in-country counterparts in the techniques.

16 PARTNERS IN EDUCATION: USU AND BOLIVIA
Dale J. Harding
Give a person hope and a viable way to pursue its realization—and you’ve affected more lives than just that one. USU educators have had that kind of far-reaching impact abroad. School and library buildings have been constructed, books produced, and teachers taught. Some direct effects are easily seen. The less direct may persist through generations.

22 CIDIAT: CREATING A WORKING CENTER
Bruce H. Anderson
A remarkable cooperative effort produced a method for combining on-the-job and classroom experiences for policymakers, managers, and technicians. The full effects on food production that have been realized because of the CIDIAT-initiated improvements in land and water management may never be known.

26 ENRICHED SOILS: RICHER HARVESTS
D. W. James
Without soils no crops could be produced in a standard fashion. But each soil has unique properties that must be identified and manipulated if plant growth is to be optimal. USU soil scientists have worked with both scientists and farmers in less developed countries to help them learn the necessary techniques.

30 INCREASING CROP PRODUCTION
Keith R. Allred
No matter where he or she is living, every farmer wants to get more from the land. Much of our crop-related work in less developed countries has directly helped their farmers achieve that objective. At the same time, we have gained access to plant materials that will eventually increase the returns of our own farmers.

36 IRRIGATION: BASE FOR DEVELOPMENT
A. A. Bishop, G. H. Hargreaves, and E. C. Olsen III
Proper application and management of precious water can make the difference between a harvest and a crop failure. As they have helped solve irrigation problems around the world, USU investigators have often found answers to similar difficulties close to home.

40 INTERNATIONAL FEED SYSTEMS
L. E. Harris, L. C. Kearl, and P. V. Fonnesbeck
To produce well, livestock must eat well. An international effort is being made to obtain, standardize, and computerize data about locally popular feedstuffs in terms of their nutritive values and names.

44 RANGELANDS: A FRONTIER IN DEVELOPMENT
B. E. Norton
Many less developed countries have extensive acreages of land that is best used as range. Too often, however, the land and the animals that graze it function far below their potential productivity. By helping define what needs to be done to correct specific situations, range scientists are actively combating world hunger.

48 ANIMAL PRODUCTION IN DEVELOPING COUNTRIES
Warren C. Foote
In many of the less-developed, protein-starved countries, sheep are a preferred source of meat. USU personnel are making vital contributions to programs designed to identify and optimize the productivity of breeds of sheep especially suited to particular environments throughout the world.

54 BEYOND TECHNOLOGICAL BAND AIDS
Derrick J. Thom
The research may be with plants, animals, water, soil—but the ultimate goal is always to help individuals better their lives. To be effective in this regard requires attention to and in-depth knowledge of those individuals, their traditions, values, and dreams. USU specialists in sociology, geography, anthropology, and similar disciplines are making contributions toward satisfying that need.

60 CONCLUSION
Doyle J. Matthews

ABOUT THE COVER
PHOTO BY DERRICK THOM
Raising shovels as though going into battle, this Mwethya women’s self-help group terraces the land for growing crops.
IN THE 1830s, the world population reached one billion. A hundred years later, in 1930, the world population had doubled to two billion. In just 30 additional years, in 1960, a billion more had been added. Today the world population stands at 4.5 billion. It is estimated that by the year 2000, there will be about 6.3 billion people on the earth.

This will require a vast increase in the world’s food production. It has taken since the beginning of man’s history to acquire sufficient know-how to feed the present population and, aside from those living in the United States and a few other industrialized nations, that population is being fed none too well. Just 20 years from now, we will be trying to feed another two billion people. That, of course, does not mean that we have 20 years in which to prepare for such production. Rather, it means that each year between now and then, we must increase production in proportion to the yearly population increase. Agriculture has come a long way in a relatively brief period of time, but if it does not surpass the past record, we will face a food crisis of a much greater magnitude than the straits imposed by energy shortage.

As the world’s greatest agricultural producer and history's richest nation, the United States must bear the heaviest burden in meeting this awesome challenge. For the past four decades, America has been sharing its agricultural bounties with other nations. The challenge of the United States in the future will be to share its expertise and resources in a way that will help the peoples of the third world increase their own expertise and productivity, especially in agriculture.

This issue of UTAH SCIENCE presents an overview of long-term work done abroad by Utah State University scientists that has a special bearing on world hunger. The United States cannot produce enough food within its own borders to supply all the hungry of the world. USU personnel have therefore joined with individuals from other universities to help people in less developed countries help themselves. I cannot think of a more important priority for the United States in its relations with third world communities than a strong commitment to their economic development—especially agricultural development with emphasis on increased food production.

As a final point, may I reemphasize my belief that the development of human capital and institutions to serve agriculture in host nations is one of the most effective uses of US foreign assistance resources. If we succeed with this effort, we will have established a base whereby these nations can raise themselves from substandard, and in some cases subhuman, living conditions. I would like to conclude this preface on the aspirational note sounded by the Presidential Commission on World Hunger:

"The Commission is convinced that if decisions and actions well within the capability of nations and people working together were implemented, it would be possible to eliminate the worst aspects of hunger and malnutrition by the year 2000. Such an undertaking would contribute immensely to global peace and security, to the welfare of the human family, and to the national interests of all countries."

STANFORD CAZIER
Early 1960s corn distribution to Greek farmers brought interest in instruction to improve their own crops.

CLARK BALLARD
INTERNATIONAL PROGRAMS AT USU (1915-1981)

THE BEGINNINGS

President John A. Widtsoe invited Mirza Ali Gholi Khan, Consul General for His Majesty the Shah of Persia (Iran), to speak at the Baccalaureate Services at Utah State University (then Utah State Agricultural College) in 1915. This action was the first major international programs contact made by the university. The next exchange came in 1939 when Reza Shah Pahlavi invited Dr. Franklin S. Harris (who became president of USAC in 1945) to be his special advisor regarding water, soils, and crop management development. Dr. Harris and his wife moved to Tehran in 1939. Soon after, Professors L. M. Winsor and Don W. Pittman were assigned to work on irrigation and agronomy development throughout Iran as well as to teach at Karaj Agricultural College. This relationship was terminated by World War II.

Following President Harry S. Truman's enunciation of his Point IV program in 1949, five US land grant universities were invited to participate in the program: 1) Utah State University (Iran), 2) University of Arizona (Iraq), 3) University of Alabama (Panama), 4) Purdue University (Brazil), and 5) Cornell University (Philippines). The resultant contract relationship between USU and Iran continued from 1951 to 1961. Team leaders included Franklin S. Harris, R. E. Bowman, R. H. Walker, and J. Clark Ballard. We next entered Iran with long-term contracts in 1973, when the USU International Sheep and Goat Institute signed a contract. James O. Bennett was named Chief of Party and Warren C. Foote was Director. In 1974, Bruce H. Anderson, acting for the Consortium for International Development (with USU as lead school), signed a contract with the Iranian Government for a dryland and livestock improvement program. N. Keith Roberts was Chief of Party for four years. Both of these projects were suspended late in 1978 because of the Iranian revolution.

Over the 15 years of our interacting with Iran, many USU faculty members had opportunities to live and work in that country on a long-term basis. Many others filled short-term assignments. A large number of Iranian students came to USU because of these contracts. Some of them are even now in important positions in the Iranian government.

BOLIVIA

The Bolivia-USU association began formally in 1965 when four families from USU entered that country with J. Clark Ballard as Chief of Party.

The Bolivian relationship started only after pre-contact expenditures of time and effort by USU people. President Daryl Chase, Austin B. Haws, and others made several visits to Latin America and to Washington, DC over a two-year period before the contract materialized. The goal (as in Iran) was to help the people in a less developed country increase their agricultural productivity and thus find a way out of the hunger-fatigue-poverty cycle.

We have now been in Bolivia for over 15 years as the contractor or lead school under a CID contract. The work has ranged from improving sheep-wool-mutton and llama-hair-meat production to identifying ways to better forage-crops-livestock-water-market-soils management. Institution building, sector planning, policy formulation, research, extension, and training have consistently commanded substantial efforts. During the 15 years of the contract, Bolivians have been trained by our faculty at USU, at their universities, and in other places. Subsequent to Ballard's team, other Chiefs of Party have been Haws, William F. Farnsworth, E. Boyd Wenneberg, David W. James, and James H. Thomas.

The educational effort inside Bolivia was directed at youngsters at primary and secondary levels. Orson Tew and Dale Harding headed this program for a number of years. With the cooperation of the Utah Partners of the Alliance, Utah school children, USU contract personnel, and village people in Bolivia, a large number of rural schools were built over a period of 10 or more years, and educational potentials were materially widened.

CIDIAT

In response to the interest and efforts of Dean F. Peterson, Bruce H. Anderson, and many others, the Centro Interamericano de Desarrollo Integral de Aguas y Tierras (CIDIAT) was created in 1965. CIDIAT operated out of Merida, Venezuela, under a contract with the Organization of American States. Many people at all levels of government in Latin America were trained at the center and in their own countries to solve water and other rural and agrarian resource policy, development, and management problems. The program, which was eventually turned over to the member countries, is still actively combating hunger in Latin America.

Agricultural and Irrigation Engineers from USU have been involved in international work for many years. Hardly a country exists that has not been influenced by these people. As an example, A. Alvin Bishop organized and conducted training courses in water control and management in Japan and the Mideast for a number of years. Dean F. Peterson, Howard Peterson, Jack Keller, and many others have provided leadership in this work elsewhere in the world.

USU's historical involvement in international programs has merely been sampled here. Virtually every department has had some noteworthy experience. In fact, nearly 200 faculty members have had long- or short-term assignments in the international field, thereby enhancing agricultural and educational productivity around the world. Inevitably an office was established to coordinate international
activities at USU. In 1965, Austin B. Haws was asked by President Daryl Chase to become director of the International Programs Office. He was followed in 1968 by J. Clark Ballard and in 1970 by Bruce H. Anderson. The present director is E. Boyd Wennergren.

The president of a university obviously influences programs by his actions and expressions for or against them. From Franklin S. Harris, who resigned his presidency when he returned to Iran on his second tour, to Stanford Cazier, the presidents of USU have supported international involvement. This is especially true of Presidents Chase, Glen L. Taggart, and Cazier. For example, President Cazier, testifying before the Subcommittee on Foreign Operations of the Senate Appropriations Committee on April 1, 1980, said:

"We (at Utah State University) are committed to continuing the relationship between the US development program and US universities. We endorse the broad concepts that Congress approved by enacting the Title XII Amendment to the Foreign Assistance Act of 1975. In particular, we commend the mandate that universities should have a significant role in technical assistance, and the recognition of the need for a dependable source of federal funding to facilitate university participation in future efforts to assist developing nations."

**IN SUMMARY**

A summary of USU's international activities and their ramifications follows:

1. Over the past 30 years, USU has had 70 projects in foreign countries. (These long- and short-term contracts do not include the numerous contracts entered into privately by faculty members.)
2. The 70 contracts have brought about $30 million to the university and the state of Utah.

3. Over the last 40 years, the number of foreign students on campus has averaged about 900 per year.

4. The foreign students at USU inject about $8 million a year into Utah.

5. At the present time, USU personnel are involved with six long-term projects in foreign countries. These projects are operating independently or through the Consortium for International Development. The countries include Bolivia, Tanzania, Cape Verde, Guatemala, Honduras, and Somalia.

6. Over the past five years, virtually every developing country in the world has been visited by a USU faculty member on assignment.

7. About 200 USU faculty members have had some international experience.

8. USU has 26 campus projects that strengthen our international awareness. These projects are supported by a government Title XII grant of about $165,000 per year matched with USU funds.

9. The USU Area Studies Program in International Development provides an opportunity for students to expand their understanding of various societies, their problems, and languages.

10. USU personnel are involved with a Women-In-Development project centered in the Consortium for International Development. Women in the developing world are worse off than the men, and they do much of the work in food production and preparation. Nevertheless, they have not been receiving help and consideration their situation deserves.

11. USU organizations such as the International Sheep and Goat Institute, the International Irrigation Center, and others have earned good reputations in countries where their personnel have served. They are involved in research and training with international consequences.

12. The East-West Center at USU has brought prominent speakers onto campus to increase our awareness of other societies and our relations to them.

13. The Center for the Study of the Causes of War and Peace, established over 20 years ago, has continued to draw attention to critical international problems.

14. USU's 50 students in the Foreign Participant Training project (cooperatively organized with the US Department of Agriculture) are studying ways to improve the productivity of human and natural resources in their own countries.

15. Approximately 850 other foreign students are on campus from many countries gaining educations that they hope will benefit them and their countries.

16. As a member of the Consortium for International Development consisting of 11 western universities, USU has staff members participating in foreign projects that have other CID schools as lead schools.

17. Special language courses are available for staff interested in preparing for foreign assignments. Also, intensive English is taught for foreign students who are deficient in the language when they arrive.

18. For a long time, USU has had a Foreign Student Office that helps the students adjust to the campus and American culture, assists them when problems arise, and watches over their interests.

Other activities are in the planning stage at this time. On-campus programs in Life Span Learning are being developed with international focus. Curricula and course material are being examined in some departments with the goal of including more of an international flavor. Several international projects are at varying stages of development.

The main thrust of the university has been to prepare its students for, and have faculty capable of, research into problems anywhere they may occur in the world. A sample of recent research and training efforts made by USU representatives on the broad campus of the world fills this issue of UTAH SCIENCE.

REFERENCES

Iran and Utah State University and Bolivia and Utah State University are two excellent reviews of major projects. Edited by Gwen Haws, they contain early USU international history along with considerable project detail.

ABOUT THE AUTHOR

N. Keith Roberts is Project Leader, International Programs and Studies, Professor in the Economics Department, Bolivia Project Director for Consortium for International Development (CID), and for Somalia Project, USU.
Since the end of World War II, the United States has accepted economic and technical assistance to the developing world as an integral part of its foreign policy. The rationale for this commitment has two dimensions. First, there are obvious humanitarian concerns for the world’s hungry. Second, there are the self-interest motivations of the United States.

Humanitarian concerns are easily demonstrated and can be readily embraced by most Americans. The need for food has been cited as a basic human right, and yet, the President’s Commission on World Hunger has reported that one out of every eight people on the earth is hungry most of the time. From other sources we learn that the number of children who die of malnutrition each year in the developing world equals the number of children under 15 in the states of California, New York, Illinois, and Texas combined. Any hope for self-induced changes in these conditions seems absurd so long as over 600 million people remain mostly illiterate and must try to survive on incomes of less than $50 per year.

Obviously, US technical assistance most directly benefits the underprivileged of the world who are the realities behind such statistics.

Programs providing food, medicines, and medical help, as well as those designed to promote indigenous food-producing capabilities within the developing nations have one overriding objective: to improve the lives of poverty-ridden people. Toward this end, the United States allocates more money than does any other nation. For example, in 1979, the US disbursed $4.6 billion to developing nations. This can be compared to the $3.4 billion from Germany and $2.6 billion from Japan, as examples. Yet the United States ranks only about 16th on the list of nations when total support is expressed as a percentage of each nation’s Gross National Product (GNP). The US contribution represents only .19 percent of its GNP. The highest percentage is contributed by Sweden, at .90 percent of its GNP. Another kind of comparison is also revealing. While as a nation we contributed $4.6 billion to international assistance in 1978, as individuals we were spending $30.6 billion on alcoholic beverages, $17.9 billion on tobacco products, and $5.9 billion in barber shops and beauty salons.

Projections for the future suggest that, whatever the motivation, a more effective effort must be implemented immediately to help the world’s 4.1 billion population before it doubles by the year 2020. In confronting this bleak truth, it is well to keep in mind that humanitarianism can often benefit the givers in unexpected ways.

A few brief examples can illustrate this point.

1. As less developed nations (LDCs) become more affluent, they simultaneously become paying customers for products from our farms and factories, and more accessible sources for us for raw materials so essential to our economy and national defense. US exports to LDCs have tripled in the past five years. These same nations now buy 37 percent of our manufactured exports. This exceeds our exports to industrialized Europe and is three times the amount we send to Japan.

2. Approximately 1.2 million American jobs depend on exports to the developing world. About one out of four acres of American farmland produces food exported to the LDCs. This market represents about $10 billion annually.

3. Of the US dollars designated for international assistance, about 90 percent reportedly are expended in the United States for goods and services produced here.

E. Boyd Wennergren

The photos on the opposite page are a sampling of sights captured by USU photojournalist, John S. Flannery, on the African continent. The top right picture records the erosion of farmable lands which is occurring with alarming frequency.
But perhaps the best example of how self-interest is served by humanitarianism rests in the alternative we face if the world's poor are not properly nourished. This was most trenchantly expressed by N. Keith Roberts in his 1980 Faculty Honor Lecture at USU:

"We can ignore the ultimate implications of a starving, ignorant race and the waste of productive resources over time. The result would surely be the unleashing of nuclear power in one mighty race-destructive war for control of food and space. Make no mistake; food and space control will be the basic causes of that war no matter how the politicians or philosophers define the conflict.""

The deleterious impacts of widespread world hunger on life in the US will be massive in comparison to those we now (or may eventually) experience because of the energy crisis.

**Benefits to the State of Utah**

Humanitarianism and self-interest pragmatics are equally relevant whether international assistance is viewed from a state, regional, or a national perspective. Therefore, Utahns likely differ very little from other areas of the nation in their concerns about technical assistance abroad. Citizens of Utah have historically associated themselves with humanitarian causes and can take legitimate pride in having state institutions such as USU intimately involved in solving international agricultural issues.

A study completed at USU in 1979 identified some of the self-serving benefits that are accruing to the state as a result of USU's participation in these institutional activities. Four of these bonuses are discussed below.

- **The Contracts Themselves**
  All contract agreements for technical assistance provide for budgetary support of programming costs administered by USU. Salaries paid to faculty while abroad, transport and shipping of families and their goods, of necessary supplies and equipment are just a few examples of the costs covered by the contracts. A significant portion of these monies are expended in Utah. Furthermore, all contracts pay in full for indirect overhead costs to the university and state.

- **Foreign Students**
  USU's involvement abroad has had a significant influence on attracting international students to the university. These students do not displace any Utah applicants, and they spend considerable monies on university fees, housing, food, taxes, etc. which help support Utah's economy. Furthermore, they add a positive cultural dimension to the university and community.

- **Technology Transfer and International Commerce**
  The ostensibly unilateral flow of technology often benefits the state and nation. Most developing nations possess crop varieties and other agronomic assets that can be important to our productive capability. Utah's "Blood Tomato Story" is detailed elsewhere in this issue as one example. According to some plant breeders, sunflowers and cranberries are among the very few plants that are native to the US. Corn and potatoes, for example, came from Central and South America and wheat from the Middle East. Water management techniques perfected elsewhere can prove invaluable at home. One prime example is the Senegal River Management Model, which has been profitably applied to the Provo River. Similar material benefits have been reaped in international commerce.

- **Quality of Education**
  International involvement inevitably affects the quality of the educational process at a university. Faculty develop a new and stimulating dimension in their teaching efforts, the curriculum becomes more relevant to world realities, student interests are expanded, and their educational experiences assume urgent validity. Community/faculty interactions can also be improved as faculty share their experiences with local clubs and other organizations.

**Specific Analyses**

Two of these four identified impacts of international assistance were subjected to a quantitative evaluation to
assess their economic importance. An analysis of the monetary value of technical assistance contracts, per se, and of the expenditures of international students attending USU showed the following:

1. Since 1951, international assistance contracts at USU have amounted to an estimated $29.8 million. This averaged just over $1.0 million annually.

2. Slightly more than one-half of the contract activity has occurred since 1972. The annual dollar volume during those years (1972-1979) amounted to almost $2.0 million.

3. Of the total contracts amounts, an estimated $19.6 million has been expended in Utah.

4. During the 29 years that were analyzed (1951-1979), international activities generated an estimated $4.0 million in overhead cost dollars returned to the state, or an average of $140,000 per year. Since 1972, the annual overhead returns have approximated $250,000.

5. The estimated salary support gleaned from international contracts (primarily for faculty abroad, but including short-term consultants and limited on-campus support) can be translated into about 17.3 person years annually.

6. The major long-term technical assistance contracts that have been completed in 10 developing nations and the three similar projects currently in process have produced and are producing a full complement of benefits to Utah and the nation.

7. The 924 international students attending USU in 1979 expended an estimated $7.9 million, for an annual average of $8,591 per student.

8. Fifty-six percent of their expenditures were on tuition, food, and housing. From 1977-1979, USU's international students as a group spent at least $1.0 million dollars annually on each of these items.

9. From 1951-1979, international students' expenditures averaged $2.2 million annually in Utah, with considerably higher amounts occurring in more recent years.

10. Based on an input/output analysis for 1979, the overall multiplier effect of the USU technical assistance activities was 2.13.

In dollar terms, such a multiplier means that the $9.6 million expended in 1979 in Utah for technical assistance contracts and by international students generated approximately $20.0 million in statewide economic activity.

Viewed in human terms, the situation is less readily measured by money. Indeed, it seems inappropriate to talk about dollars and self-interest in relation to starving human beings. Yet the realities of politics and public finance demand that we try to analyze this problem in a non-emotional context and regardless of the rationale employed.

Assistance to the developing world by its very nature generates demonstrable benefits for the donors. This should not be viewed as reprehensible. In fact, this can be viewed as the best of all possible worlds so long as the primary objective remains assisting the world's poor and not developing the self-interest of the United States, as has sometimes been the case.

Past international activities by both the US and USU have suffered from an absence of enlightened public support. The magnitude of the consequences we face, by almost any objective measure, demands public awareness and resultant support. The world's underprivileged need to have US citizens understand and articulate their situation. Utahns can become part of this altruistic yet self-serving effort by informing themselves about the issues and making a commitment to vocal and material participation in the work. This issue of UTAH SCIENCE represents one expression of USU's belief in a need to extend public awareness.

We invite you to consider the alternatives and to then join us as we do what we can to combat world hunger.
ONE WAY TO HELP DEVELOPING COUNTRIES solve their food production and distribution problems is to identify costs, benefits, and capital requirements as they relate to proposed solutions. About 18 USU economists have filled long or short tours in less developed countries (LDCs) making the needed analyses. In-country technical specialists have made invaluable contributions to the basic information used by the economists.

In their analyses, economists evaluate available and possible technologies, policy implications of alternatives, production and marketing systems, and proposed rural development programs. The results have been used for planning purposes and decision-making at central government, regional, local, and individual levels. In the analysis process, it is possible to determine present and potential demand and supply levels; the impact of programs on the country's balance of payments; the impact of anticipated changes on population distribution; and the private and public costs and benefits of "forced" progress. Some examples of USU economic analyses done for LDCs are presented.

Counterparts

In Bolivia, as in most LDCs, in-country counterparts were essential to USU economic studies. There have been many such individuals; too many to discuss in the detail each deserves. Percy Aitken Soux, who was the first counterpart for USU economists in Bolivia, will serve as representative of them all. Aitken came from a landed family that had lost most of its land in a revolution in the early 1950s. He had a BS degree from a US university. Raised with Quechua Indians on the family hacienda, he spoke Quechua and Aymara (Bolivian Indian languages), as well as Spanish, English, French, and Portuguese. His knowledge of the Indian languages enabled us to accomplish otherwise impossible tasks.

One particular train trip from LaPaz to Charaña on the Bolivian border was typical of how Aitken functioned in helping us help his country. It took 10 hours to make the 200-mile trip, whose purpose was to establish and evaluate wool and hair marketing stations in remote Western Bolivia.

On that trip, as on many other occasions, Aitken used the time to give his USU counterparts some understanding of the ways of the contrabandistas; Bolivia's social, political, economic, and religious institutions; village life; and the history, archeology, anthropology, and herbology of the country. For example, through him, his counterparts came to know the subtle roles filled by husbands, wives, and children in Bolivian family life and how village social structure functioned. As a result, USU personnel could match their teaching efforts to the proper people in livestock management, marketing, and planning.
Bolivia—
Artisan and Yarn Cost Studies

People often think that artisan hand labor technologies (Figures 1 and 2) can put sweaters, rugs, wood carvings, etc., on the market much more cheaply than can machine technologies. Yet, in the 1960s, retail prices in the US for some Bolivian artisan products were higher than for similar domestic, machine-made products. Since considerable AID and Bolivian money was being spent to let Bolivian artisans tap the rich US market, there was a need to find out if they could effectively compete in the US market. A detailed cost study was made for Bolivia’s FOTRAMA artisan cooperative. Four different kinds of woven rugs and two kinds of ponchos or sweaters were studied. The hand processes of production constituted costs for each of the selected products to which was added a share of overhead costs.

During a market survey trip through the US, it was discovered that retail prices for similar products made by machines in the US from hair and wool imported from Peru and Bolivia were much lower than the break-even prices required in Table 1.

A study then was made of the domestic yarn plant at Pulacayo. The technology being used, along with the disadvantages associated with location, raw material supplies, and the state of competition from other places made it unlikely that Bolivian yarn producers and users could compete in the world market. One major result was a more realistic reordering of Bolivia’s development priorities.

Bolivia—Wool Studies

In 1965, the USU team found that very little wool was being marketed from Bolivia’s 6 million sheep. What did reach market was dirty and in the form of hanks and tags. Producers made no attempt to grade or package the raw wool. Most wool used directly by producer families was pulled off pelts of dead animals. What little shearing occurred was done with tin cans or glass. At the same time, Bolivia was annually importing about $1.5 million worth from neighboring countries. In Bolivia, a 20 kg sheep was considered large (US sheep average 50 kg), and each fleece weighed about 1.0 kg (an average US fleece weighs 3.5 kg).

We saw wool as an unutilized cash crop that could affect the standard of living of producers as well as improve Bolivia’s balance of payments status. But every phase from production through marketing had to be changed to achieve worthwhile results. Several actions were initiated by the USU team.

The textile industry was contacted. Plant managers agreed to buy domestic, graded wool. A pricing scheme was established with prices differentiated by grade.

With the help of the Bolivian Extension Service and the government wool marketing agency (COMBOFLA), Darrell Matthews and others of the USU team held shearing schools for producers and families in the villages (Figures 3 and 4). Hand shears were imported and made available at a subsidized price. Fleeces were kept clean, rolled, and graded. COMBOFLA paid cash on the spot for the sheared wool, and then delivered it to the textile mills, who in turn paid the guaranteed prices (Figure 5).

A breeding program to upgrade flocks was started by importing improved rams (Figure 6). They were placed in cooperator herds whose owners gave their common rams in exchange. In the third generation (1.5-2.0 years) the offspring of the imported rams weighed 40 kg each and were producing as much as 3 kg per fleece at top grade.

The demonstrations were so convincing that over 200 shearing schools were held between 1965 and 1973. COMBOFLA purchases of domestic wool jumped from zero in 1965 to 240,000 kg in 1973. Over 4,000 pairs of shears were sold to producers.

When Bolivia’s sheep program was analyzed in 1974, annual costs were subtracted from the annual benefits that had resulted from the program between 1965-1974. The internal rate of return to the sheep program was thereby calculated to be 44.1 percent. Wool production and processing had become profitable for all parties.

Agricultural Data

Bolivia’s agricultural sector has long suffered from inadequate and limited data, which inevitably makes planning a
TABLE 1. Costs for Producing by Hand Methods Selected Artisan Products in Bolivia, 1965

<table>
<thead>
<tr>
<th>Product</th>
<th>Weight or Size</th>
<th>Total Cost</th>
<th>Costs of Marketing in U.S.*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brown Esmirna Alpaca Rug</td>
<td>2.25 m²</td>
<td>$35.37/m²</td>
<td>$141.48/m²</td>
</tr>
<tr>
<td>White Esmirna Alpaca Rug</td>
<td>2.38 m²</td>
<td>35.39/m²</td>
<td>141.56/m²</td>
</tr>
<tr>
<td>Brown Alpaca Poncho</td>
<td>1.20 lbs.</td>
<td>10.18/unit</td>
<td>40.72/unit</td>
</tr>
<tr>
<td>White Alpaca Sweater</td>
<td>1.75 lbs.</td>
<td>13.76/unit</td>
<td>55.04/unit</td>
</tr>
<tr>
<td>Brown Alpaca Tipica Rug</td>
<td>2.64 m²</td>
<td>15.72/m²</td>
<td>62.88/m²</td>
</tr>
<tr>
<td>Dyed Esmirna Wool Rug</td>
<td>.83 m²</td>
<td>23.82/m²</td>
<td>95.28/m²</td>
</tr>
<tr>
<td>Dyed Esmirna Wool Rug</td>
<td>1.93 m²</td>
<td>26.94/m²</td>
<td>107.76/m²</td>
</tr>
<tr>
<td>Dyed Tipica Wool Rug</td>
<td>2.21 m²</td>
<td>15.05/m²</td>
<td>60.20/m²</td>
</tr>
</tbody>
</table>

*Export duties from Bolivia, shipping, U.S. Customs, wholesale mark-up and retail mark-up brought the breakeven price to four times the Bolivian production costs.

hazardous exercise in futility. The last agricultural census had been made in 1950, and its utility was doubtful because of the social changes that followed the 1953 revolution. When USU advisors arrived in 1965 (Figure 8), the economists collaborated with Ministry of Agriculture and USAID officials to propose and implement four principal activities that would strengthen and improve Bolivia’s agricultural data base: 1) a comprehensive survey of rural consumption and production; 2) development of improved sampling methods for estimating crop production in key regions; 3) analyses of the production and marketing of sixteen of Bolivia’s principal agricultural products; and 4) development of market price reporting services.

The rural-urban survey was conducted in 1972 to obtain data on production, consumption, and socioeconomic variables. Samples were taken in each of Bolivia’s ten major ecologic zones, with a total of 2,500 households being surveyed. Out of those endless numbers, charts, and tables came benchmark estimates for 1972 relative to the production of most Bolivian agricultural products and their domestic use; income and expenditure elasticities; and projections of supply and demand for these agricultural items. The data were also used to corroborate other independent estimates of production, and in preparing Bolivia’s five-year agricultural plan.

USU economists also helped the ministry analyze the costs of production and net returns for sixteen of Bolivia’s most important crops. The studies provided a wealth of economic data, as well as excellent training for ministry personnel in project evaluation.

**Sector Analysis and Planning**

In 1965, one USU economist proposed a program for assessing the agricultural sector. The Bolivians needed help in learning how to analyze problems; to formulate coordinated policies for appropriate public sector program and services; to set priorities for use of scarce public funds; and to improve the organization and administration of public services. USU-aided sector studies and planning efforts were consistently directed towards increasing the productivity and the standard of living of the small-scale, poor, and often hungry Bolivian farmers.

Initial efforts were focused on improving the capability of Bolivia’s Ministry of Agriculture to carry out agricultural planning, to analyze the economic viability of alternative activities, and to improve the agricultural data base. Both long-term and short-term advisors taught intensive courses for credit from USU’s regular curriculum on an extension class basis while in Bolivia. At the same time, several Ministry of Agriculture employees completed graduate degrees in agricultural economics at USU and other institutions under grants from AID.

In 1973, a USU economist helped Bolivia’s Office of Planning assess the country’s agricultural sector, as a basis for formulating public policy and setting investment priorities for the sector. Much of his contribution was based on research that had been previously carried out and described in a manuscript entitled *The Status of Bolivian Agriculture*. The final result was a twovolume *Diagnostico del Sector Agropecuario, 1974* (Assessment of the Agricultural Sector, 1974), which was and remains an important contribution to public policy analysis in Bolivia.

The subsequent Plan Quinquenal del Sector Agropecuario: 1976-80 (Five-Year Plan of the Agricultural Sector: 1976-80) includes a comprehensive set of supply and demand projections for major agricultural commodities. All projects proposed for the agricultural sector by various Bolivian government agencies were tested against criteria in the five-year plan, and then priority ranked. Operative plans for 1977 and following years were developed on this basis.
Support to USAID/Bolivia

USU economists have directly supported the USAID/Bolivia mission by participating in the conceptualization, planning, and evaluation of various facets of the total aid program, and by preparing associated documentation. The 1973 USAID Sector Assessment was the basis upon which the USAID mission programmed its development assistance activities in Bolivia’s rural sector for the rest of the 1970s. These included a sector loan and grant of over $20 million. The book, The Status of Bolivian Agriculture (authored by USU economists), and USAID’s Sector Assessment volume, are still the authoritative English sources on Bolivian agriculture today.

USU economists also assisted the USAID mission in preparing a variety of program documents related to various aspects of the development assistance program. Included were papers describing the New Lands Development Loan in 1973, the Agriculture Sector Loan and Grant in 1974, and the Coca Crop Substitution project in 1975. In carrying out these assignments, a USU economist was assigned as special advisor to the Rural Development Office, USAID Bolivia.

Policy Studies
The economic and agronomic potentials for wheat production in Bolivia were evaluated in 1966. Despite the economists’ findings that wheat is a very marginal crop for Bolivia, the USAID mission emphasized wheat production while reducing the relative size of the Altiplano livestock program in the late 1960s and early 1970s.

Another major policy study focused on the economics of overgrazing of Bolivia’s extensive rangelands. Our economists first traced the historical origins of the common property nature of Bolivian rangeland use. Their resultant formal economic model explained the nature of Bolivia’s common property problems and their associated misallocation of resources. The principal finding was that “...rangelands are exploited as common property resources with resulting overgrazing, consequent depletion of the range resources, and an inherent external diseconomy in the form of flooding and erosion as vegetation is destroyed.” The principal policy implication of the study was “...that property rights to maintain rangeland in Bolivia must be given and enforced if grazing intensity is to be reduced.” In its Spanish translation, the study was widely distributed in Bolivia.

USU economists have participated in a number of other key policy studies including: 1) the feasibility of substituting alternative crops for coca (the source for cocaine); 2) the supply response capacity of Bolivian agriculture; 3) the economic value of roads and other infrastructure to support colonization of new land areas; 4) agricultural price policy; 5) marketing of principal Bolivian crops; and 6) substitution of other grains for wheat in producing flour.

Iran—Crop and Livestock Management
USU economists have filled missions to other countries, too. For example, in 1974, a CID/USU team went to Iran to help increase wheat and meat production in that country. Although Iran had the resources to produce all the wheat and meat necessary to feed its population with some left over for export, the country was importing large quantities of both products. The team worked on large corporation farms, using their management and other resources.

The most dramatic results were obtained in mutton production by five corporation farm flocks and this case will be used as an example. When the team arrived, the sheep management system was as follows: sheep were considered scavengers. They grazed the already overgrazed hills (Figure 12). Grass, grain stubble, or weeds were the main sources of feed for most of the year. Very little grass was consumed per animal due to over-stocking of the ranges. During the winter, sheep were enclosed in caves or in cellars under the houses and fed poor quality roughages. Unproductive animals were rarely culled. An animal left the herd when it died. Herd inbreeding had been common for generations and had led to a multiplication of genetic freaks that were unproductive. Nothing was done to correct for the animals’ extremely fat, broad tails which complicated breeding and led to low lambing percentages. Because of the feeding system, lambs were seldom marketed; instead, only animals that weighed about 40 kg per head (usually at 24-27 months of age) reached markets.

Herd improvement practices were introduced soon after the specialists
arrived in Iran in 1974. Sheep housing facilities were modified to increase air circulation throughout the year, breeding seasons were defined, lambs' tails were docked, individual animal records were started, herds were culled, rams from other Iranian breeds were introduced to flocks, open corrals were erected, self-feeders were built, mechanical shearing was introduced, feed rations were developed for each class of sheep in a herd, disease and parasite control measures were improved, lambing conditions were upgraded, and some modern machinery was purchased.

The results achieved by using the introduced herd management techniques can be summarized as follows. Over a period of two years, 100 ewes under traditional management had been producing about 35 lambs that were marketed weighing 40 kg each. Under the introduced management techniques, 100 ewes produced at least 160 lambs in two years, with each lamb weighing at least 45 kg when marketed. The result is a 4.7 times increase in productivity for 100 ewes. These minimum productivity changes, if they were generally achieved throughout Iran, would more than eliminate the need to import sheep or mutton.

Analyses projecting five years into the future were made for sheep, wheat, dairy milk, dairy beef, and range forage production on eight corporation farms in Iran. The projected rates of return on investment for each enterprise at the Azna Corporation farm are in Table 2.

<table>
<thead>
<tr>
<th>Enterprise</th>
<th>Year (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sheep feeding and breeding herds</td>
<td>7 8 7 15 29</td>
</tr>
<tr>
<td>Dry farm wheat</td>
<td>19 27 50 85 139</td>
</tr>
<tr>
<td>Dairy milk</td>
<td>9 25 30 35 41</td>
</tr>
<tr>
<td>Dairy beef</td>
<td>-85 16 68 74 97</td>
</tr>
<tr>
<td>Range forage</td>
<td>-249 57 79 132 536</td>
</tr>
</tbody>
</table>

Costs are naturally high in the first year or two while dramatic improvements in productivity do not occur until later.

**Broad Implications**

All of USU's economics-oriented studies, training programs, and educational pursuits in developing countries are designed to raise the productivity of each country's human and natural resources. Only in that way can presently poor, hungry, and illiterate people achieve a sustainable improvement in their standard of living. Altruistic as well as selfish motivations are involved. Improving the lives of fellow human beings is a goal, but so also is the creating of markets for our own troubled economy.

At the enterprise level in LDCs, much can be gained without introducing technologies that demand substantial capital investments. Crop yields in many places can be increased at least four times by improving present management systems through a few low-cost techniques. Once the first steps have been successfully demonstrated, management progress increases rapidly.

People in developing countries are more than willing to change when they are convinced that by changing they can improve their lives. Through their analyses, economists determine whether or not the potential benefits are likely to exceed the predictable costs of change. People are characteristically reluctant to modify traditional ways until they are convinced the change will not cost more than it is worth. In LDCs, when the costs exceed the returns, babies and grandparents die. Economic analyses or valid data help preclude such risks.

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THERE IS A STRIKING RELATIONSHIP between a nation's educational system and its economic growth and self-sufficiency. An excellent example is found in Bolivia, where almost every natural resource known to man exists in good abundance. But with Bolivia's educational development one of the lowest in Latin America, a large percentage of Bolivians barely survive on a day-to-day basis.

FIGURE 1
Rural library facilities were generally nonexistent, or at best might consist of a few books such as in this village.

FIGURES 2 and 3
Whenever books were brought to the rural people, appreciative crowds gathered.

FIGURE 4
School and library buildings in rural areas of Bolivia were generally built as village projects. Whoever could help did what he could.

FIGURE 5
The depth of this stream and the lack of any ford or bridge meant that a delivery of books had to either be returned to their city source or be hand carried across by the men of the village.
The Need for Change

USU’s 1966 analysis of educational conditions in Bolivia contributed the following diagnostic information: (1) of every ten children born, three died before they were one year of age and two more died before reaching five; (2) 100 percent of the rural children under ten years of age harbored some type of round worm, ring worm, hook worm, or dysentery; (3) 100 percent of Bolivia’s rural people were infected with serious communicable diseases in their life span; (4) the average life span in Bolivia was 36 years and 70 percent of the population was under 30; (5) six of every ten citizens were Indians who spoke only Indian dialect languages and therefore were treated as less than first class citizens; (6) only 26 percent of Bolivia’s rural children began school; (7) of each one hundred children who started school, only three graduated at the junior high level; (8) lacking education (69 percent were classed as illiterate), 81 percent of the population contributed nothing to the national economy; (9) 72 percent of all Bolivians were rural farmers with access to only two percent of the tillable land, and (10) per capita income averaged $70 per year. Yet, Bolivia contained oil, natural gas, timber, rubber, rich grazing lands, fertile black soil three feet deep in some ‘reas, and every mineral known to man.

In 1966, recognizing education as a critical key to optimizing the use of their country’s natural and human resources, Bolivia began an intensive effort to improve their educational system. The first goal was to locate a university that could provide a professional educator who would come to Bolivia. That educator was to help the Bolivians make their educational system an agent of social, economic, and cultural changes that would meet the needs of the country. USU was chosen, and B. Orson Tew became Bolivia’s first Education Advisor. He and his family were in Bolivia from August 1966 until July 1969. After working four years in Chile developing educational programs and visiting Bolivia several times as an educational consultant, I followed Tew and was in Bolivia from July 1969 to August 1972.

Administrative Preliminaries

To begin implementing the changes wanted by Bolivians, a conference on Bolivian education was held in LaPaz in October 1967, with participants from both rural and urban ministry personnel. Special consultants included John C. Carlisle, Dean of Education at USU, and Lloyd McCleary, Dean of Graduate Studies in Education at the University of Illinois, along with representatives from OAS, UNESCO, UNICEF, and Ford Foundation. Five additional experts from neighboring Latin American nations also participated.

Besides giving direction to future USAID and Bolivian educational projects, conference participants saw their conclusions incorporated into the law that was later written to govern education in the country. Bolivia’s Education Reform and Supreme Council on Education were other direct results of the conference.

In 1969, I developed a Needs Assessment process and we helped a team of Bolivians poll people in every state and in every language regarding the educational goals and objectives they wanted for Bolivia. Then, in a first time cooperative effort by rural and urban administrators to improve Bolivian education, national objectives were unrealistic, and highly abstract. Rural and urban education efforts were completely separated in budget and theory, while teacher training, especially for rural educators, was seriously inadequate, and textbooks and/or study guides for use in the rural areas were almost nonexistent (Figure 1).
rewritten and approved by the Bolivian government. B. Orson Tew, Technical Advisor in Education; Professor José E. Carrillo, National Director of Teacher Education; and Professor Arnaldo Majia, National Director of Rural School Teacher Education, were the organizers and catalysts. The resultant targets for Bolivian educational development became USU’s comprehensive ten-year plan for helping Bolivians achieve what they had had in mind in 1966. Our ten-year goals became:

1) Identify, and assign a priority order to, training projects essential for the country’s economic and social development and the newly stated national goals and objectives of education.

2) Implement those projects that fell within the framework of the financing potential and technical assistance available through the International Development Association.

3) Determine the amount and type of assistance necessary to bring the projects to a state of functional use.

4) Identify measures the Government of Bolivia must take to assure continuity in the success of the projects in a balanced and efficient educational system.

5) Initiate efforts to achieve the long-range objectives of educational plans and programs within the financial and other capacities of the country to support the proposed development.

Utah State University personnel would provide the technical assistance needed by local educators to meet both national and local goals and objectives.

**The Work Begins**

After a conference of experts and the polling of the Bolivians, and with objectives defined, we started to organize a Curriculum Laboratory in cooperation with third country advisors and Bolivians. The purpose of the laboratory was to develop curriculum materials that would update the public schools of Bolivia and help them meet the country’s educational needs. Local educators were to be trained at the laboratory so they could produce curriculum materials needed in their sections of Bolivia. A science series, a reading series, and a math series of texts, along with a curriculum guide for each subject were written and produced by personnel of the Curriculum Laboratory.

Despite transportation and production problems, we eventually produced, published, and distributed over 1,000,000 books (Figures 2 and 3). District seminars were held nation-wide to provide in-service training in the use of the new materials to supervisors and principals. They in turn gave seminars for the teachers who would introduce the materials to classroom situations.

Bolivia’s Curriculum Laboratory became a model for other Latin American countries. It is still producing excellent materials and training teachers.

**Scholarship Programs**

From 1966 to 1972, approximately 159 scholarships were granted to Bolivian university students. Each scholarship of about $1,400 allowed the recipient to study in a major American university. Several of these scholars studied at Utah State University in conjunction with Bolivia’s Curriculum Laboratory training program. All scholarship recipients were obligated to return to Bolivia to give service, or they were to refund the amount of their scholarship. Many who gave service also refunded their scholarships for use as a permanent loan fund for future Bolivian students.

One outstanding example of student achievement is the work Felix Gomez did to develop media and color printing for use in the textbook program of the Curriculum Laboratory in LaPaz. Because of his work in USU’s media program, laboratory texts were eventually printed in six colors at the same cost that was originally calculated to provide just two. These books rank among the best in Latin America, and have been used as models by other countries.

**Libraries and Literacy**

With the cooperation of the Regional Technical Center (RTAC), headquartered in Mexico and funded by USAID, we distributed more than 230,000 books and pamphlets to the rural areas of Bolivia between 1969 and 1972. During the same time, 168 small libraries were established in rural Bolivia, where 82 percent of the country’s total population lives. These libraries were built by the people themselves (Figure 4) and thus became part of their lives and a source of community pride and activity. This new access to literacy and books was seen as a help toward escaping life’s hunger/fatigue/misery cycle.

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*Sprint 1981 19*
The people-to-people approach of the Utah/Bolivia Partners program consistently emphasized self-help. Whether the specific project involved building a school or a library, training medical and dental technicians, or showing farmers how to improve the quality and quantity of their produce—the process centered on people helping people.

The response of the people in the village of El Toco to 500 RTAC books was typical. Heavy rain had swollen the river bordering El Toco so that not even a four-wheel drive vehicle could get through on the delivery day. Unwilling to wait for better conditions, however, men from the village repeatedly waded across the booming, chest-high waters of the river, holding a few books over their heads until all 500 were safe and dry on the village side. They then hand-carried their precious cargo to their newly built community-school library (Figure 5).

To combat the estimated 70 percent illiteracy rate in Bolivia, over 100,000 high interest (for adults), low vocabulary, reading books were developed, published, and disseminated using resources of the Human Resources Division of USAID. This project united the efforts of Bolivian educational planners and the USU/USAID education advisor and produced 168 adult education centers across the nation in rural areas.

Teaching the Teachers
During the six years that USU provided education advisors to the Bolivian ministry, more than 55 national and regional seminars for teachers were conducted throughout Bolivia under the auspices of the Human Resource Division of USAID. The subject areas included: science, reading, language arts, mathematics, physics, chemistry, administrative supervision, curriculum development, school organization, and teacher education. The emphasis was always on developing curriculum and teaching strategies appropriate to the culture and needs of the Bolivian people. Twenty-nine pamphlets were written and distributed through the Curriculum Development Library.

By August 1972, the number of teachers and administrators attending each year’s seminars was exceeding 13,000 (Figures 6, 7, and 8). The professional growth of the Bolivian teachers and their eagerness to implement innovative ideas and materials in the schools of Bolivia testified to human responsiveness when offered a chance at self-improvement. In turn, the youngsters in their classrooms became infected with hope and enthusiasm.

In 1979, I was able to return to Bolivia for a visit, specifically to Manteguilla, a small village in the mountains of the Yungas of Bolivia. When we began the improvement process in 1968, no one in the village was attending school for lack of facilities, teachers, and materials. In 1979 the new school the people of the village had built was staffed by five trained teachers, who were using materials available from the Curriculum Laboratory. The day school was serving 178 primary students, while adults were attending literacy classes in the evenings (Figures 9 and 10).

Developing Schools
In 1966 a program of improving normal (teachers') schools was initiated by Dr. Tew when Bolivia’s Ministry of Rural Affairs received a grant for that purpose. The grant included schools at Caracollo, Warisata, Santiago de Huata, Paracuya, and Canasmovo. Plans called for constructing at each site: a water system to provide running water, dormitories for students, a cafeteria, a laboratory for science use, and model classrooms. All projects were completed by 1972 using local volunteer labor to a large extent.

Libraries were developed at each school with books provided by the RTAC program. As part of this effort I wrote six science textbooks that were published by Bolivians for use in all teacher-training centers in Bolivia.

A technical school was organized to provide classes in trades such as plumbing, carpentry, masonry, and electricity to rural young people at minimal cost. With USU leadership, in three years 389 Bolivian Indian students had graduated with competence in one of the above fields. Although many of these students could not read or write, they had learned a trade that lets them work in construction projects in Bolivian cities. Despite Bolivia’s subsequent political unrest and revolutions, this school (maintained and operated by the Rural Ministry of Education) has never been closed.
A Partner Approach

Through the Utah/Bolivia Partners' program, committees organized in Bolivia and Utah have promoted: education in agriculture; cultural pursuits and the arts; business, civic, and social clubs; dentistry, medicine, and eye care; athletics; women's activities; and mining. The Partners' participants filled major needs in friend-making and by developing programs complementary to the USU technical assistance programs. The following are typical of the hundreds of localized educational and self-help projects (Figures 11, 12, and 13) that were successfully built on a people-to-people concept:

1) Interchanges of 4-H students and advisors were accomplished.

2) General agriculture: Sheep improvement and trading, sheep slaughter house, seed improvement, chicken and rabbit raising have all received attention.

3) Educational materials have been distributed to schools where USU projects in agriculture were operating.

4) Wool improvement: Grading, processing, and manufacturing (rugs, sweaters, ponchos, etc.) activities have been upgraded.

5) Technical assistance: Community development efforts have been helped.

6) School construction: Over 100 schools have been built with funds donated by citizens of Utah, especially Utah's school children.

7) Library construction has been encouraged and books have been supplied.

8) Dental and medical help and training have been provided throughout Bolivia.

9) Exchange projects: Hundreds of people have shared their talent and expertise with counterparts in Utah and Bolivia. Participants have ranged from groups as large as the Utah Symphony and Tabernacle Choir to a single basketball coach who conducted clinics. Cultural exchanges such as art exhibits, musical groups, etc. have been made.

10) Equipment projects: Dental equipment (including an X-ray machine), medical supplies and equipment, school desks, and 25 tons of clothes, tools, toys, and blankets (in a Christmas airlift) have been provided.

KSL-TV in Salt Lake City gave a black and white television transmitter to the Utah Bolivia Partners.

The Partners' people-to-people, self-help program created a friendship bond that will not easily be eroded. The process was best expressed by a comment of an old Indian from Bolivia's Altiplano, "Gracias a Dios que nos ha mandado gente tan humilde, inteligente y bondadoso para trabajar mano a mano con nosotros. Ustedes son verdaderos amigos." Which means, "Thank God that he sent us intelligent, humble, kind people to work hand in hand with us. You are true friends."

Around the world, people suffering from malnutrition and its effects would be delighted to respond as the Bolivians have to personalized self-help. The sending of money is a relatively easy conscience-sop, but rarely is it effective over the long term. To escape from hunger, those who are trapped must be helped to learn how to make their resources more productive on a sustained basis.

Not All One-sided

Financial gains came to USU through overhead cost dollars from each project. Then too, over 100 Bolivian students have enrolled at USU, often bringing family members with them. These ranged from first-year students to MS and PhD candidates.

Less tangible benefits are associated with individual Utahns who gained an improved understanding of the people of Bolivia, while people in Bolivia have come to know Utah and her people. Thousands have been involved in this interchange. When Bolivia's President Barrientos visited USU he said, "It is not an idle statement to say that I am privileged to be at Utah State University because Utah holds a very special place in my heart. Strong bonds link us together. Utah now has an unprecedented people-to-people tie with the nation of Bolivia. There exists an inextricable faith that Utah people care and want to help others."

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CIDIAT:

CREATING A WORKING CENTER

BRUCE H. ANDERSON

THE 22 MEMBER NATIONS of the Organization of American States (OAS) are acutely aware that they must increase their food production. The OAS therefore requested that USU establish a center where key personnel could learn how to best develop and use land and water resources to increase production of food and fiber. Based on a contractual arrangement, USU began work on this challenging project during the fall of 1964. The result was to be an Inter-American Center for the Integral Development of Land and Water Resources designed to serve the needs of Central and South America. (The anachronym CIDIAT comes from the Spanish title of the Center, Centro Interamericans para Dessarollo Integral Aqua y Tierra.) But creating the Center required more than a wand waving. A curriculum, a philosophy, and a methodology had to be devised that would match the needs of the Latin American countries. Among the questions that had to be answered quickly, were:

1. Where should the Center be located?
2. To whom should training be given?
3. How should selected participants be taught?
4. What should be taught at the Center and at what level?
5. How can one Center meet the needs of 23 countries that have vastly different problems?

After a meeting of USU deans and administrators had assured support for
the Center’s development, two workshops were held involving selected, non-USU consultants. Members of each workshop devoted a week to considering the above and other questions before making recommendations. The first set of consultants was chosen on the basis of experience in training programs in South America.

The second group of consultants consisted of representatives from the member nations of the OAS. Key personnel from the agencies concerned with land and water development were invited and 15 countries responded. From the expressions and the recommendations of the consultants, it was evident that, while certain courses could be taught effectively at the Center, others would have to be taught in individual countries to meet their specific needs.

Reports, recommendations, and a proposed curriculum outline were prepared and a director was hired to begin implementing and establishing the Training Center.

Concepts and Procedures

It had been decided to locate the Center at the Universidad de los Andes in Merida, Venezuela. The Government of Venezuela as well as the Universidad de los Andes and the Organization of American States would each contribute financial support to the Center. The staff was to be international, with no more than three of its members coming from any one country. The Center also was to be careful not to unduly “rob” any national development organizations of competent staff. The Center’s core curriculum was to emphasize basic principles of land and water development and their applications to solving practical problems. At the same time, training was to be provided for several student levels, e.g., administrators and policy makers, arid land managers, teaching/research professionals, and technicians. The Center also had a mandate to collect and develop library and teaching materials and make these available in the Spanish language.

Host Country Planning

An exchange of visits between the two universities to be involved occurred. The President of USU visited ULA at Merida, and later in June, 1964, the Rector of ULA visited USU in Logan to discuss the project and establish terms for the collaboration between the two universities.

The final agreement to establish CIDIAT included the following major objectives:

- "Train through regular short and intensive courses, professionals and high level officials; to develop their administrative capacity in order to increase the effectiveness of their present work in the adequate use of natural resources; to coordinate the operation of existing facilities and improve the maintenance and administration of land and water projects.”

- "To promote the interchange of technical information and ideas between professionals and administrators in this field.”

- "To improve existing institutions concerned with land and water development projects.”

The agreement further stipulated that:

- "The training program should be carried out by means of seminars, short courses, regular courses, and research related to training, and the project will have a time limit of six years as of the 1st of January, 1964.”

To assure continuation of the aims of CIDIAT, the agreement provides that:

- "A year prior to the termination of the project, the two parties will initiate the arrangements for the definite transfer of the project, and adds that once the project has been transferred, the host university will continue the activities of the Center as a regular program of the university without the financial assistance of PTC.”

The Implementation Process

CIDIAT was officially established in Merida, Venezuela, in May 1965 and its first program was given in July 1965. As the program evolved, it offered the following core courses:

1. One- to two-week seminars for persons in policy-making positions.
2. Short courses lasting approximately two months for persons of mid-management level who have eight or more years of experience in working with land and water problems.
3. Courses of approximately six months duration for professionals with two to eight years of relevant experience.

In-country and Special Courses

1. National Training Programs.

These efforts were designed to meet the specific needs of individual countries, and usually lasted one month each. The training staff assigned to teach an in-country course would arrive in the country several days before they were to start. They would study the problem area so that their examples and teaching materials reflected as realistically as possible the types of problems project personnel were encountering. This approach was perfected at CIDIAT, and became very effective in introducing a technical assistance component into a training program.

2. Executive Managerial Training.

This innovative CIDIAT program lasted 3-5 days.

3. Regional Training.

This program was developed to meet similar needs shared by several countries when no one country could provide sufficient personnel to justify a national training course.
FIGURE 2.
This flock of sheep has been carefully selected to provide a basis for an improved breeding programs.

FIGURE 3.
USU advisors and Chilean agriculturists inspect corn experiments and tomato plots which were subjected to controlled irrigation and fertilizer applications resulting in greatly increased yields.

FIGURE 4.
Majaguas irrigation project used by CIDIAT for case study in project development.

FIGURE 5.
The view from CIDIAT.  PHOTOS BY AUTHOR
A basic concept in the development and operation of CIDIAT has been to innovate and encourage creativity in the teaching process. The case study approach was extensively used to give direct technical assistance on solving real problems.

The Language Problem
CIDIAT used a simultaneous interpretation system to accommodate professors who were not fluent in Spanish or Portuguese.

Transition and Continuity
As indicated in the original agreement, Utah State University was to transfer the operation of the Center to the Universidad de los Andes at an appropriate time. As an integral part of the universidad, both the national and international components of the program were to be continued. This transition took place during 1971 and 1972. The Organization of American States still provides some support for the international component. In June 1980, CIDIAT celebrated its 15th anniversary as a special training center.

During its life span to date, CIDIAT has provided training opportunity to 4,175 Venezuelan participants, and 2,654 non-Venezuelans. It has developed an impressive library in land and water resources, including books, pamphlets, and staff publications. The Center has gained a reputation for quality teaching and is emphasizing research and providing opportunities for its staff and students to pursue research programs. During the project, 12 USU faculty served long-term assignments of two years or more in Venezuela. Twenty-two faculty assisted with short-term consultations.

Ways and means are under consideration to continue the collaboration between Utah State University and the Universidad de los Andes.

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Soils/Crops

A CID* / BOLIVIA RESEARCH AND EXTENSION PROJECT was initiated in mid-1975 under a contract with Bolivia’s Ministry of Agriculture. That 7-year contract called for personnel to investigate and improve production management practices for potatoes and small grains in Bolivia’s mid-level valleys and highlands (Altiplano) and for corn, rice, and oilseed crops in the lowlands. We will first discuss potatoes as an example of the research that is being conducted under the 1975 contract.

Potatoes in the Bolivian Highlands**

Potatoes, which originated in South America, are a crucial part of the diets of most Bolivians. Indeed, through much of the highland country, the potato is as indispensable to human survival as is rice in the Orient. For that reason, an increase in the quantity and quality of potatoes could substantially better the nutrition of much of Bolivia’s population.

A series of soil fertility trials was conducted throughout the important potato growing regions of Bolivia each year of the research project. The elevation of the trial sites ranged from about 8,000 to 14,000 ft (2,424 to 4,242 m). Results confirmed earlier observations that phosphorus in Bolivia’s highland soils frequently limits potato production. During two crop cycles (1978-79 and 1979-80), a total of 19 trials involving phosphorus (P) fertilizer were established on small farms. Of these trials, 18 were successfully carried to conclusion. Four of the 18 locations showed no potato yield response to phosphorus fertilizer, apparently because the soil had been previously fertilized with animal manures or commercial fertilizers. Yields at the zero fertilizer rate on these four sites were fairly respectable, ranging from 15 to 20 T/ha. Data shown in Table 1 refer only to those locations that responded to fertilizer.

Yields for the 14 trials (Table 1) at the zero fertilizer level averaged 7.45 metric tons per hectare, but with P fertilization the average yield was 15.77 metric tons, for an average increase of 111.7 percent. The yield range across all locations without P fertilization was 3.87 to 12.63 T/ha. With fertilization, the yield ranged from 6.2 to 27.2 T/ha. The percentage yield increase at individual sites ranged from about 30 percent to 380 percent. All P responses were in the presence of applied N fertilizer. There was an N x P interaction in most cases indicating that P was required to obtain the desired results from N.

Counting all 18 experiments conducted during this 2-year period, 78 percent of all locations responded to fertilization. Bolivia’s potentially phosphorus-responsive sites can be segregated from non-responsive sites using soil tests to quantify available phosphorus. The most effective rate of P fertilizer application could then be derived from soil test phosphorus correlation work. Unfortunately, only a well-trained laboratory staff and a well-equipped laboratory could handle the thousands of soil samples that would be needed each year for the entire country. This means that few Bolivian farmers will be able to rely on having soil analyses to tell them how best to manage their soil until the lab facilities and necessary trained manpower are available.

Potato farmers in Bolivia are already well aware, however, that their soils are infertile. Few realize that phosphorus is the ingredient needed, but they do know that dramatic yield responses can be

*Consortium for International Development, which is composed of 11 western universities. In Bolivia, USU was the lead university for a team that included scientists from four of the other universities.

**Robert Kunkel and Gonzalo Claure were the principal investigators in the potato work discussed here.
ENRICHED SOILS: RICHER HARVESTS
obtained by applying commercial fertilizers and/or animal manures. Animal manures are so highly prized that cattle, sheep, and llamas are corralled nightly in order to facilitate collection of the manures for later use on the land or for sale to other farmers. Poultry manures are also collected in commercial poultry enterprises, and sheep, cattle, and poultry manures are transported long distances for sale to potato farmers. As an example, one farmer reported purchasing sheep manure at approximately 3,600 pesos per hectare ($US144/ha). In Bolivia, where annual income per capita averages less than $US200, such an investment would not be made if the expected returns weren’t substantial.

Our ultimate goal of improving potato production thus duplicated the objective of Bolivia’s Ministry of Agriculture and her farmers. The agricultural economy of Bolivia, however, does not facilitate improvement of crop yields through improved soil management. The problem on the one hand is a lack of markets where farmers may buy their supplies (e.g. fertilizer, herbicides, insecticides), and on the other, of facilities where they can bring their products to be graded, sold, and shipped.

The results presented here for phosphorus and potato production call attention to another difficulty plaguing the world’s poor. Crops produced on adequately fertile land are more abundant and richer in nutrients. The resultant foods are more economical to buy and more nutritious for both animal and human consumption. Agricultural improvements in any country thus should start with attention to its soils.

Based on our potato and other research, short-term and long-term practices were recommended to the Bolivian Ministry of Agriculture that could help facilitate the production of more and better quality food. In regard to fertilizers, a short-term expedient would be to eliminate import duties on these and other agricultural chemicals. Existing import duties customarily increase the purchase price by more than 100 percent. This makes fertilizers too expensive for the farmers and limits the food available to Bolivia’s non-farmers.

Over the long run, Bolivia could develop its abundant low-grade phosphate rock by applying new technologies. Bolivia could thereby satisfy its in-country needs for phosphate fertilizer and develop an export market for a commodity that is in demand in all neighboring countries.

**Lowland Bolivian Soils**

In contrast to the highland (Altiplano) soils, soils in Bolivia’s lower eastern plains around Santa Cruz are highly fertile. USU/CID personnel have been involved in extensive field trials there on corn, rice, soybeans, and, to a lesser extent, on sunflower and sesame. In these trials, we have investigated various kinds and rates of fertilizers, together with soil moisture and pest controls. No positive crop responses to phosphorus fertilizer have been observed on any trial in this area, and soil chemical analyses confirm an abundance of available soil phosphorus. This phosphorus evidently originates in the outcroppings of Bolivia’s low-grade phosphate rock. As the material weathers, it is being transported to the alluvial fan that is developing off the eastern edge of the Andes Mountains.

Soil and crop management studies were made on small farms in Bolivia’s sub-humid zone around Santa Cruz. These production trials included mainly upland rice, soybean, and corn crops. Table 2 shows the results from three locations for rice, which were typical for all crops tested. There was no response at any site to phosphorus fertilization. The differences between locations were mainly associated with variable precipitation. It is anticipated that intensive crop management may be carried out for several years in this area before soil phosphorus will be reduced enough to require fertilizer additives.

**Other Latin American Soils**

USU personnel have conducted soil fertility and management studies in conjunction with various projects in El Salvador, Guatemala, Honduras, Colombia, Brazil, Chile, and Peru. In all cases, the ultimate goal has been to increase crop (food) production.

The young volcanic ash soils (deposited with the last few hundred years) in Guatemala, El Salvador, and Honduras are usually well supplied with phosphorus and potassium but need help from nitrogen. On the other hand, older soils in these countries, derived from both volcanic ash and sedimentary materials, are reddish in color (i.e., rich in iron and aluminum oxides) but have been leached of their nutrient elements (calcium, magnesium, potassium, and phosphorus). As a result, they are very unproductive without multi-mineral fertilization. Soil chemical analyses can easily identify such fertilizer needs, but reliable soils laboratories are difficult to locate in most South and Central American countries.

**Frustration in Colombia***

In 1970, we were asked to help solve a problem near the north coast of Colombia. The government had reclaimed about 40,000 hectares of land from annual flood cycles of the Magdelenia River by diking and had then installed an elaborate irrigation distribution system. Despite these and subsequent efforts, it had been impossible to develop a viable irrigated agriculture in that area.

We also failed to establish successful crop production on the heavy clay soils after 14 cropping trials conducted over a period of 20 months. The field trials we carried out had irrigation as the main factor but soil fertility and other amendments (including nitrogen, phosphorus, potassium, sulfur, boron, iron, manganese, magnesium, copper, gypsum, and lime) were also tested. A great deal of variability existed in the yields of all our test crops (corn, sorghum, sesame, cotton, and soybeans, and both upland and paddy rice).

Affected plants were generally chlorotic soon after emerging. The upper leaves of the young plants were deformed and tended to stick together. In later stages of growth, severe stunting was a characteristic. Necrotic

***The Colombia project had Tom Fullerton as its principal investigator."
patches occurred on the perimeters of the older leaves and general interveinal chlorosis was present. The corn, for example, reached only a fraction of its ordinary height, produced very few ears, and sometimes died. Farmers in the area had previously decided that nothing except grasses would grow well. Growth disorders were also present in the pasture grasses but to a lesser extent.

Modest responses were obtained from some of our test crops with low rates of nitrogen fertilizer. In other cases no effects were seen. Nitrogen was judged not a part of the crop growth problem since our results could be explained by previous fertilization practices. No positive responses to phosphorus fertilization were obtained with any crop, but sesame underwent a significant yield decrease with the application of 50 kilograms of phosphate per hectare. No effects of any kind were observed when potassium, sulfur, lime, gypsum, or boron were added to the soil, nor from foliar-applied iron and magnesium. One positive visual response was seen with foliar-applied manganese, but this evidently had no lasting effect on the crop.

A series of tests indicated that no disease factor could be definitely connected with the growth disorders.

Ultimately, soil samples were brought to the campus at Utah State University and analyzed for 11 physical and chemical parameters. It was determined that total phosphorus in the soil samples was 5 to 20 times higher than in normal arable soils, while extractable iron, copper, zinc, cobalt, and nickel were high to very high as compared with normal soils.

Our 24-month Colombia project allowed us no final conclusions. Tentatively, we concluded that the excessive elements as determined by the USU soil analyses were of geologic origin and therefore part of the indigenous soil-mineral complex. It was further concluded that these soils could not be reclaimed by routine procedures.

The only definitive conclusion that we could report was that investments in land drainage and the construction of an irrigation network should always be preceded by tests to establish the potential productivity of crops under the proposed conditions.

Farmers in less developed countries (LDCs) rarely have access to sophisticated help in managing their soils. For them, as for early American pioneers, increasing crop production often has to be largely by trial and error using natural fertilizers and common sense. Nevertheless, soil scientists from American universities can indirectly assist the farmers in LDCs to improve their productivity. The key is to encourage and help the in-country educational institutions achieve two goals: a training and equipping of technicians, and the extension of practical information to the farmers.

ABOUT THE AUTHOR
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**TABLE 1. Phosphate Fertilizer Yield Trials on Potatoes, Bolivia, 1978-79 and 1979-80.**

<table>
<thead>
<tr>
<th>Location</th>
<th>Zero Kg/ha</th>
<th>120 Kg/ha</th>
<th>Percent Change in Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>1978-79</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tiraque</td>
<td>10.91</td>
<td>15.77</td>
<td>44.6</td>
</tr>
<tr>
<td>Piscomayo</td>
<td>5.63</td>
<td>27.23</td>
<td>383.7</td>
</tr>
<tr>
<td>Chulichulcani</td>
<td>8.84</td>
<td>19.71</td>
<td>123.0</td>
</tr>
<tr>
<td>Racay Pampa</td>
<td>3.87</td>
<td>16.79</td>
<td>333.8</td>
</tr>
<tr>
<td>1979-80</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Piscomayo 1</td>
<td>7.00</td>
<td>24.10</td>
<td>244.3</td>
</tr>
<tr>
<td>Piscomayo 2</td>
<td>3.20</td>
<td>8.35</td>
<td>160.9</td>
</tr>
<tr>
<td>Tiraque 1</td>
<td>5.08</td>
<td>7.58</td>
<td>49.2</td>
</tr>
<tr>
<td>Tiraque 2</td>
<td>8.65</td>
<td>13.63</td>
<td>57.6</td>
</tr>
<tr>
<td>Chulichulcani</td>
<td>12.63</td>
<td>20.08</td>
<td>59.0</td>
</tr>
<tr>
<td>Llachumayo</td>
<td>11.73</td>
<td>15.23</td>
<td>29.8</td>
</tr>
<tr>
<td>Chinini 1</td>
<td>8.95</td>
<td>10.78</td>
<td>20.4</td>
</tr>
<tr>
<td>Chinini 2</td>
<td>4.70</td>
<td>6.20</td>
<td>31.9</td>
</tr>
<tr>
<td>Racay Pampa</td>
<td>6.10</td>
<td>14.30</td>
<td>134.4</td>
</tr>
<tr>
<td>Totala</td>
<td>6.93</td>
<td>21.05</td>
<td>203.8</td>
</tr>
<tr>
<td>Mean:</td>
<td>7.45</td>
<td>15.77</td>
<td>111.70</td>
</tr>
</tbody>
</table>

*All phosphate fertilizer plots at all locations received nitrogen fertilizer and in some cases potassium fertilizer. The phosphorus was supplied as concentrated superphosphate or ammoniated phosphate and the nitrogen was supplied as ammoniated phosphate or urea, depending on the nitrogen-phosphorus fertilizer combinations.

**TABLE 2. Fertilizer Experiments on Upland Rice, Santa Cruz Area, Bolivia.**

<table>
<thead>
<tr>
<th>N-P-K Fertilizer Combinations</th>
<th>San Pedro</th>
<th>Portachuelo</th>
<th>Yapacani</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kg/ha</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-0</td>
<td>6.92</td>
<td>6.95</td>
<td>2.03</td>
</tr>
<tr>
<td>80-0-150</td>
<td>6.72</td>
<td>7.10</td>
<td>2.47</td>
</tr>
<tr>
<td>80-15-150</td>
<td>6.35</td>
<td>7.46</td>
<td>2.45</td>
</tr>
<tr>
<td>80-30-150</td>
<td>6.64</td>
<td>7.87</td>
<td>2.40</td>
</tr>
<tr>
<td>80-60-150</td>
<td>6.65</td>
<td>7.38</td>
<td>2.36</td>
</tr>
</tbody>
</table>

**Don Kidman and Erwin Ortiz were the principal investigators. Data shown are averages of four replications. No significant treatment effects were observed.**
INCREASING CROP PRODUCTION

IMPROVED CROP PRODUCTION for food and feed is one of the most urgent needs in most developing countries of the world. Our faculty members have served both long- and short-term assignments in technical assistance for countries of Central America, South America, the Middle East, and Africa. In this paper, primary attention will be given to the results obtained by our plant scientists while providing assistance to the people of Iran and Bolivia through two long-term contracts. In providing that assistance, however, our researchers soon realized two facts: their success or failure often hinged upon the help they received from farmers themselves and in-country scientists; and, as they gave help, they often saw benefits developed that reached beyond local borders.

**Varietal Trials Serve in Evaluating Crop Performance**

A valuable method of determining the adaptability of a crop variety to the growing conditions of a country is through varietal trials (Figure 1). Crop varieties or types that have been selected for certain soil and climatic conditions in one country occasionally might be adapted to somewhat similar growing conditions in another country. When such varieties are identified in a trial, the benefits from the years of research that went into the perfecting of that variety can be reaped immediately in the agricultural program of the other country.

A few months after the first USU advisory team arrived in Bolivia, the forage specialist, DeVere R. McAllister, began to collect seed of especially promising forage species from various parts of the world for testing in Bolivia. He assembled fifty different types or varieties of alfalfa, fifty entries of other legumes, including the most common clovers, birdsfoot trefoil, sainfoin, and vetches, and one hundred fifty types or varieties of grasses generally considered to be adapted to the temperate regions of the world.

Varietal trials utilizing this broad collection of forages were established at three of the Agricultural Experiment Stations across the Altiplano: Belen, Patacamaya, and Chinoli, as well as on the Puna School farm. The following year another trial was established at the Condoriri Agricultural School near Oruro.

The responses of these various forages to the region's climatic and soil conditions differed tremendously. Based on performance data obtained from the variety trials and considering the availability of seed, recommendations were made for putting the following forages into production on the Bolivian Altiplano (see Table 1).

**Garden Vegetables Provide Variety for Daily Diet**

"For centuries, the gardens of Persia (Iran) have been immortalized in song and verse. These ornamental gardens, while contributing aesthetically to the life of many wealthy city dwellers, have done little to improve the lot of the millions of peasants. In some 44,000 villages of Iran where malnutrition abounds, vegetables are practically unknown with the exception of the revered cucumber and an occasional onion."

These were some observations of J. Clark Ballard, USU Horticulturist, early in his assignment to that country in 1951 (Figure 2). So, in cooperation with the Ministry of Agriculture, he initiated a three-pronged program to educate Iranians concerning the value of having nutritious vegetables in their diet: 1) vegetable variety trials were started, 2) home gardens were encouraged, and 3) quality vegetable seeds were produced and distributed.

Fifty supervised trials were established throughout Iran in which approximately 50 different vegetable varieties were tested for adaptability, drought resistance, quality, and yielding ability. The results were definitive and the proven outstanding varieties were enthusiastically accepted (Figures 2a and 2b).

Home demonstration gardens were developed in areas where landlords, peasants, and students alike could be taught the techniques of growing vegetables. They saw how even small garden plots could contribute to a better quality of life. Literally thousands of people watched the development of the demonstration garden plots and varietal trials. By the end of the growing season, requests had begun to come in from distant parts of the country as the news spread. The people wanted at least sample quantities of the productive seeds for personal use during the next growing season.

A key objective of the overall program was to produce sufficient amounts of quality seed of the proven varieties for distribution to gardeners. This was accomplished by involving the Ministry of Agriculture, Karaj College, and a number of private growers in the production efforts.

Starting in 1952, an effort was made to introduce some improved American varieties of vegetables together with the furrow culture planting method. The furrow method presented many advantages, especially with garden tools, weeding, and aeration. United States varieties basically were better than local types as a result of the breeding and selection process they had undergone.
Demonstration Plantings
Interest Farmers
In Bolivia, on the other hand, when the forage trials had identified the best producing crop varieties for different locations, a series of seed kits were made up and distributed for use in a field demonstration program. This proved to be a highly effective way to interest campesino (peasant) farmers in using improved forages (Figure 3). Each seed kit contained ten of the best forages as selected by the varietal trials. For Bolivia the kits contained: 1) Ranger alfalfa, 2) Moapa alfalfa, 3) Kenland red clover, 4) Alta tall fescue, 5) Alkar tall wheatgrass, 6) weeping lovegrass, 7) orchardgrass, 8) Greenar intermediate wheatgrass, 9) Russian wild ryegrass, and 10) either Reed canarygrass or Nordan crested wheatgrass, depending on whether the demonstration was to be planted on a site that tended to be wet or dry.

The seed kits were distributed to the campesino farmers by Agricultural Extension Agents, Peace Corps Volunteers, Community Development Leaders, and members of local Agricultural Cooperatives. Over six hundred seed kits were distributed for planting throughout the Altiplano. In general, the forage demonstrations were planted on better than average soil, and in several instances were fertilized and irrigated. Many of them were in areas that could be protected from grazing animals by adobe walls.

This program allowed individual farmers to evaluate the performance of these forage varieties under their own soil and climatic conditions. It was then fairly easy to convince the farmers to grow these high producing crops for use as pasture, hay, or silage.

### TABLE 1. Forages Most Suitable to the Bolivian Altiplano

<table>
<thead>
<tr>
<th>Forage</th>
<th>Variety and area or condition where recommended</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa</td>
<td>Ranger and Moapa: Throughout the Altiplano, especially where water is available for irrigation and salt is not a problem.</td>
</tr>
<tr>
<td>Red Clover</td>
<td>Dallard: For the northern Altiplano area around Lake Titicaca.</td>
</tr>
<tr>
<td>Orchardgrass</td>
<td>Throughout the northern Altiplano area and in the central and southern parts where water is available for irrigation.</td>
</tr>
<tr>
<td>Tall Fescue</td>
<td>Alta and Kentucky-31: Throughout the Altiplano.</td>
</tr>
<tr>
<td>Tall Wheatgrass</td>
<td>Alkar: For humid soils in the drier regions, especially on soils with medium salt content.</td>
</tr>
<tr>
<td>Weeping Lovegrass</td>
<td>Drier areas in the central and southern parts of the Altiplano.</td>
</tr>
</tbody>
</table>

### TABLE 2. Forage Seed Imported Into Bolivia for Research, Demonstration, and Pasture Plantings, 1967-74

<table>
<thead>
<tr>
<th>Legumes</th>
<th>Pounds</th>
<th>Grasses</th>
<th>Pounds</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ranger Alfalfa</td>
<td>68,440</td>
<td>Alta Tall Fescue</td>
<td>21,900</td>
<td>80,340</td>
</tr>
<tr>
<td>Moapa Alfalfa</td>
<td>38,400</td>
<td>Alkar Tarr Wheat grass</td>
<td>9,920</td>
<td>48,320</td>
</tr>
<tr>
<td>Lahontan Alfalfa</td>
<td>6,250</td>
<td>Weeping Lovegrass</td>
<td>4,800</td>
<td>11,050</td>
</tr>
<tr>
<td>Caliverde Alfalfa</td>
<td>500</td>
<td>Orchardgrass</td>
<td>13,950</td>
<td>14,450</td>
</tr>
<tr>
<td>Sonora Alfalfa</td>
<td>2,100</td>
<td>Tualatin Tall Oatgrass</td>
<td>500</td>
<td>2,600</td>
</tr>
<tr>
<td>Kenland Red Clover</td>
<td>5,700</td>
<td>Greenar Intermediate</td>
<td>2,050</td>
<td>7,750</td>
</tr>
<tr>
<td>Hairy Vetch</td>
<td>8,500</td>
<td>Wheatgrass</td>
<td>2,050</td>
<td>10,550</td>
</tr>
<tr>
<td>Strawberry Clover</td>
<td>300</td>
<td>Russian Wild Ryegrass</td>
<td>3,350</td>
<td>3,650</td>
</tr>
<tr>
<td>Ladino Clover</td>
<td>550</td>
<td>Lynn Perennial Ryegrass</td>
<td>3,600</td>
<td>4,150</td>
</tr>
<tr>
<td>White Clover</td>
<td>450</td>
<td>Kentucky Bluegrass</td>
<td>3,850</td>
<td>4,300</td>
</tr>
<tr>
<td>Birdsfoot Trefoil</td>
<td>500</td>
<td>Reed Canarygrass</td>
<td>1,550</td>
<td>1,550</td>
</tr>
<tr>
<td>Black Medic</td>
<td>300</td>
<td>Timothy</td>
<td>300</td>
<td>300</td>
</tr>
<tr>
<td>Sanfoin</td>
<td>600</td>
<td>Meadow Foxtail</td>
<td>100</td>
<td>600</td>
</tr>
<tr>
<td>Aisike Clover</td>
<td>100</td>
<td></td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>African Alfalfa</td>
<td>50</td>
<td></td>
<td></td>
<td>50</td>
</tr>
<tr>
<td>Madird Yellow</td>
<td>100</td>
<td></td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>Sweet Clover</td>
<td>100</td>
<td></td>
<td></td>
<td>100</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td><strong>132,640</strong></td>
<td><strong>Subtotal</strong></td>
<td><strong>65,870</strong></td>
<td><strong>198,510</strong></td>
</tr>
</tbody>
</table>

### TABLE 3. Domestic Seed Production in Bolivia, 1970-1974

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1970-71</td>
<td>3,853</td>
<td>0</td>
<td>0</td>
<td>260</td>
<td>2,500</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>1971-72</td>
<td>5,275</td>
<td>0</td>
<td>200</td>
<td>630</td>
<td>1,100</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>1972-73</td>
<td>14,547</td>
<td>60</td>
<td>400</td>
<td>350</td>
<td>2,350</td>
<td>300</td>
</tr>
<tr>
<td></td>
<td>1973-74</td>
<td>11,000</td>
<td>80</td>
<td>1,000</td>
<td>1,400</td>
<td>3,000</td>
<td>868</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>34,675</td>
<td>140</td>
<td>1,600</td>
<td>2,640</td>
<td>8,950</td>
<td>1,268</td>
<td></td>
</tr>
</tbody>
</table>

Cooperative Community Plantings
Several large plantings were also made in different locations throughout the Altiplano (Figure 4) under the direction of the community leaders and with the assistance of the local farm families on community-owned land. One such project at Achica Bajo in 1967 was described as follows:

In Achica Bajo, arrangements were made with the community leaders early in the month to prepare land to be planted to pasture on October 13. When Spencer Daines and Keith Allred arrived that morning, the land had been plowed but was not prepared for planting. We questioned whether enough help could be obtained so the pasture could be seeded that day.

However, within half an hour after our arrival, men began coming with teams of oxen and women came carrying "Bolivian Golf Clubs" (clod breakers). By noon there were 32 men, 36 women, 5 children, 11 teams of oxen, 6 burros, and 12 pigs at work preparing the land. By early afternoon nearly one hectare of land was ready for planting.

We had two Planet Jr. planters. One was filled with Ranger alfalfa and the other with Alta tall fescue. Two of the community leaders took over the planters. Alfalfa and tall fescue were seeded in the same row with rows approximately 25 centimeters apart.

Two more hectares of land were planted during mid-December. There was excellent moisture and the alfalfa germinated and emerged within a week. This was so encouraging to the members of the community that they requested assistance with additional pasture plantings. As a result, two more hectares were planted, one to Alkar tall wheatgrass and the other to Alta tall fescue.

These new pasture plantings were visited frequently and a program of pasture management was worked out with the community leaders in order to obtain optimum returns from the pastures.

Accessibility to Quality Seed of Adapted Varieties
Farmers in developing countries often lack access to quality seed of adapted crop varieties. That makes it difficult to obtain respectable crop yields even though they follow other recommended cultural and management practices in growing their crops. Agricultural advisors from USU attempted to solve this problem for Bolivian farmers in two
ways. To satisfy their immediate needs, quality seed was purchased locally for distribution or it was imported from nearby countries or from the United States. The long-term solution, however, required a domestic seed improvement program.

In Iran, the College of Agriculture at Karaj had developed a wheat variety named Shahpasand that was being used primarily on college land and a few adjacent farms on a limited basis. Early in the USU program, George Stewart arranged for 60 tons of this superior variety to be traded to interested farmers on a bushel for bushel basis for their local wheat. The resulting yields were three to four times more than they could achieve with the local variety. This was especially significant since wheat is Iran's leading crop. In the next two years, under the direction of USU's A. Glenn Wahlquist, 546 tons and 380 tons of Shahpasand seed were distributed, respectively.

This positive experience with an improved wheat variety made it easier for the USU technicians to assist the Iranian Ministry of Agriculture in developing techniques for increasing improved seed of other crops.

The Bolivian farmers, however, had to rely on a new wheat variety developed in Mexico.

The Rockefeller Foundation, working in Mexico, had developed several high-yielding wheat varieties that showed very little sensitivity to day length. They thus could be grown in tropical or semitropical regions where wheat generally is not adapted.

Through a variety testing program, USU's Gordon A. Van Epps determined that Jaral-66, one of the varieties developed in Mexico, appeared to be adapted to the Cochabamba valley and some tropical regions of Bolivia (Figures 5 and 6). Although it had been tested only two years, it showed sufficient potential that J. Clark Ballard, Chief of Party of the USU contract group, decided to bring in seed despite the high costs involved.

One ton of Jaral-66 seed wheat was ordered from Mexico, to be shipped by airplane to Bolivia. It was distributed by the Ministry of Agriculture to careful growers for a seed increase. When they harvested their crops, there was enough quality seed of Jaral-66 to satisfy the needs of most other interested Bolivian farmers. Flying the seed in from Mexico had gained a whole production year for Bolivia.

Jaral-66 subsequently maintained its position as a leading wheat variety in the country for several years, and resulted in thousands of dollars of income for the wheat producers of Bolivia.

The increase in acreage planted to improved forage varieties for pasture and hay on the Bolivian Altiplano during the first decade of the USU contract was possible largely because of imported forage seeds. Nearly 100 tons of legume and grass seed were imported through the contract. Alfalfa varieties accounted for approximately 54 percent of the imported seed (Table 2).

Establishing Domestic Seed Improvement Programs

Once adapted crop varieties have been determined, a good in-country seed supply must be insured. Suitable seed must be produced locally through an organized seed improvement program.

In Iran, seeds of vegetable varieties obtained from the United States coupled with some fairly large seed lots of the improved varieties produced locally were given to the Iranian Ministry of Agriculture and the Karaj Agricultural College to help establish a foundation, pure-seed stocks program. A most promising beginning in the actual production of pure seed was achieved when vegetable growers agreed to begin producing seeds of snap beans, peas, lima beans, and sweet corn. That is the way private seed industries begin.

The first (1961) serious effort to organize a Bolivian seed production program lasted two years and was cooperative between the Ministry of Agriculture and the Interamerican Agricultural Service. Then, in 1966, Golden L. Stoker, a short-term USU consultant, visited Bolivia. He developed recommendations for the establishment of a pure seed production and certification program. In April 1969, James H. Thomas joined the USU team as the seed specialist and became involved in planning a national seed improvement program. Working with government officials he was able to help organize the Seed Certification Division of the Ministry of Agriculture.

A seed laboratory and processing plant was constructed near Cochabamba and seed cleaning plants were planned for Santa Cruz, Potosi, Chuquisaca, and Tarija. The seed processing plant and quality control laboratory (Figures 7 and 8) were constructed through the cooperation of the USU Contract and USAID.

Machinery and equipment donated to the project amounted to nearly $75,000. When completed it had a production capacity of about 792 metric tons of cereal grain seed and plans exist to enlarge the plant capacity to 3,740 metric tons per year by 1984.

The principal activity of the National Seed Program has been the multiplication, processing, and distribution of seeds for crops such as wheat, rice, oats, corn, soybeans, alfalfa, hairy vetch, grasses, and potatoes. Program personnel have also helped with: 1) importing seed varieties of wheat, grasses, and legumes for scientific study at Experiment Stations and regional farm trials to identify those most adaptable to Bolivia; 2) in-country development of new crop varieties; 3) importing and distributing commercial quantities of what and forage seeds.

FIGURES 7 and 8. Bolivia's new, modern seed laboratory and processing capacity was a major step toward making the country more self-sufficient in food production.
FIGURE 1. The adaptability of different varieties of any crop (e.g., these legumes at Patacamaya, Bolivia) to a specific environment is best determined through on-site trials.

FIGURES 2a (onions) and 2b (cabbages). In the 1950s, vegetable production finally began to take precedence over the ornamental gardens of Persia (Iran). Improved varieties and techniques were combined with seed production of adapted vegetable crops to promote practical home garden production. CLARK BALLARD

FIGURE 3. Belen Bolivia campesinos at field demonstration of forages. Direct observation of results is a potential persuader for making changes.

FIGURE 4. Some major forage demonstration plantings succeeded only because entire communities participated in land preparation and planting operations.

FIGURE 5. Mexico-developed Jaral-66 wheat proved well adapted to certain lowland areas of Bolivia.

FIGURE 6. Despite promising preliminary trials, however, the initial importation of a ton of seed was a gamble until the harvest was in and the desired seed increase was achieved.

FIGURE 9. Standard commonly grown tomato top left was crossed with the South American tomato on the right. The cross resulted in the tomatoes at the bottom of the left photograph. Through a process of additional crosses and selection, susceptible plants were removed until only plants resistant to the disease remained. The resistance was incorporated into large tomatoes with other desirable characteristics.

FIGURE 10. USU's Evans Farm is home for plant materials gathered from around the world. Many of these forage varieties are expected to contribute substantially to Utah's own forage productivity.

FIGURES 11 through 15. Bolivia's native potatoes, which still grow wild in many parts of the country, are basic to campesino agriculture. Because potatoes are so crucial to the diets of so many Bolivians, considerable effort was devoted to helping the peasants identify especially productive varieties. In other trials, fertilizer and irrigation treatments were imposed to further increase production.
Quantities of improved agricultural seeds that have been produced in Bolivia through the seed program and by
the cooperative efforts of farmers and the experiment stations since the seed
program started in 1970 are shown in
Table 3. These figures are impressive,
but what they meant to the Bolivian food
supply was even more dramatic.

**Benefits to America Through
Plant Introduction**

International involvement by USU plant
scientists not only benefits the people in
the country where they render technical
assistance, it also results in significant
benefits to the people of America. Most
crop plants that we grow in the United
States today did not originate here. We
became the agricultural giant that we are
through the cultivation and improve-
ment of plants introduced from
various parts of the world where they
originated. As examples, corn, potatoes,
and tomatoes came from Latin America,
wheat from the Middle East, sorghum
from Africa and India, soybeans from
the Far East, and forage crops such as
alfalfa and crested wheatgrass from
Persia (Iran) and the USSR.

Plant explorers thus have made
significant contributions to our way of
life as they sought plant types that could
donate the genetic base of adapted
food and forage species. For example,
in the 1930s, a USU plant pathologist,
H. Loran Blood, set out to solve some of
the serious problems plaguing the US
tomato industry. Returning to the
original home of tomatoes, he visited six
South American countries, including the
Andean region of Bolivia and Peru, in
search of tomato types genetically
resistant to damage by insects or
disease agents. He collected seed of
460 different kinds of tomatoes from
vegetable markets and remote areas of
South America.

In this collection was a small wild
plant that he called "Peru Wild" which
contained genetic resistance to a wilt
disease (Figure 9). Orson J. Cannon of
USU, following Blood's untimely death in
1948, took over the tomato research
and developed two cultivars with
resistant tomato varieties, which he
named Loran Blood and V R Moscow.

Today, nearly all tomato varieties grown
in home gardens and for commercial
production in the United States have
genetic characteristics that trace back
to Blood's South American seed
collection.

Some 150 varieties of Iranian
vegetable seeds were collected by USU
personnel and sent through the US
Bureau of Plant Inspection to the Utah
Agricultural Experiment Station for
testing. The collection included varieties
of melons, cucumbers, squash, onions,
rhubarb, and other vegetables. Some
proved good enough to still be grown in
home gardens throughout Utah.

Douglas R. Dewey, a modern-day
plant explorer, is principally interested in
forage grasses. His travels, therefore,
took him to areas where many of our
introduced species originated. He also
made a special effort to collect other
diverse types of plants containing viable
seed during his travels. In 1972, Dewey
spent three months in Iran looking for
new types of dryland grasses. On this
trip, he obtained 2,500 seed collections.
Although close to the Russian border at
times, he was not permitted to enter the
USSR. When relations between the US
and the USSR improved during the late
1970s, however, Dewey and Perry
Plummer of the US Forest Service
obtained permission to travel ex-
tensively throughout the Kazakastan
Republic on a 6-week plant collection
trip.

The 1,100 collections obtained during
this trip included mostly seed of forage
grasses and legumes, with some
vegetative cuttings obtained from
selected plants when seed was not
available. This trip was made possible
through a reciprocal agreement that
permitted Russian scientists to collect
native sunflowers in the US. The sun-
flower is a major crop in Russia and the
US was deemed a prime source of wild
types from which Russian plant
breeders could select genetically
superior material.

During the summer of 1980, Dewey
participated in a plant exploration trip
into the mainland of China. While there,
he was permitted access to parts of
inner Mongolia and the Xinjiang
autonomous region in the far west of
China. He obtained some 200 seed
collections, mostly of arid land forage
species while on that trip.

Plant collections obtained by Dewey
are being grown for observation and
characterization on the Evans Ex-
perimental Farm, south of Logan (Figure
10). Interested research scientists and
farmer groups throughout the state, the
nation, and even some international
plant breeders have visited this
collection. Genetic materials from these
plants are expected to enhance efforts
to improve forage crops in Utah and
elsewhere.

Present research activities with the
white potato give us a full circle of
reciprocated benefits. Although the
Andean region of Bolivia and Peru is the
native home of the potato and many
wild types are found there, most potato
breeding and improvement work has
taken place in other parts of the world
such as the Netherlands and the US.
Now these improved types and varieties
are being reintroduced into Bolivia by
Robert W. Hoopes, a USU potato
breeder presently on assignment in that
country.

Hoopes is collecting and testing seed
tubers and botanical seed of potato
clonal material that are resistant to
several common viruses and frost, and
are early to mature. These materials
come from Cornell University in the US,
the Max-Planck Institute in Germany,
Pentlandfield Station in Scotland,
Wageningen in the Netherlands, and CIP
(Contrto International de Papa) in Peru.
With excellent seed stock as a base,
Hoopes is making good progress in
developing higher yielding varieties for
Bolivia that will give the farmers' crops
both late blight resistance and some
frost resistance, while maintaining
acceptable shape, flesh color, and
eating quality.

Recently, Hoopes participated in a
joint British-Dutch-German-Peruvian
expedition that visited Bolivia to collect
wild Solanum (potato) species to be
used in further expanding the world
germplasm bank (Figures 11 through
15). He is also working in cooperation
with CIP on the possibility of using
botanical potato seed rather than tuber
cuttings for the planting of potatoes.
This procedure could pretty well
eliminate virus disease problems
directly associated with the tuber in
potato production, and thereby favorably
affect food supplies in many parts of the
world.

If we had received nothing more from
Bolivia than the white potato and
nothing more from Iran than alfalfa
and some arid land grasses, the overall
benefits still exceed the millions of
dollars of development aid the US has
provided these two countries.

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SINCE THE CLOSE OF WORLD WAR II, the United States has been involved in a vigorous program to help developing countries of the world become self-sufficient in producing the food required to meet their citizens' nutritional and caloric requirements. As a participant in this effort, Utah State University has had staff members on assignment overseas in many countries of the world since 1951.

The university's long history of leadership in irrigation science resulted in many members of the Agricultural and Irrigation Engineering Department staff becoming consultants in the developing world, both on long- and short-term bases. The initial effort was in Iran during the growth of the Agricultural Engineering Department of Karaj College and as an irrigation development plan was developed for the country.

Of special importance and interest to Utah were the millions of dollars of contract and grant money made available to the USU's Department of Agricultural and Irrigation Engineering as a result of staff participation in the International "War on Hunger" program. Much of this money was spent within the state for salaries, research, and services. At the same time, more superior staff were employed for the enlarged work load. Careful management of teaching and research assignments continues to give students valuable contacts with professional people representing ever widening ranges of experience and expertise. The same expanded staff applied its talents to finding solutions to Utah's water problems. International contract and grant activities thus produce exceptional graduates and better solutions to the water problems of Utah as they help the poor of the world.

From 1965 to 1980, a number of contracts were signed between the university and the Agency for International Development to provide help in formulating and conducting research projects that would improve water management in the developing countries. Much of this research was done on USU's experimental farms in Utah, with replications and on-site trials in various countries of Central and South America. Topics included interactions of water, fertilizer, and crops on various soils along with water rights and water law. Many crops common to both Utah and Latin America were studied concurrently under local Utah conditions of the developing countries where Utah State University personnel were stationed.

The staff of the Irrigation Department more than doubled in a 15-year period, with members often filling two-year assignments to stations in Chile, Brazil, Colombia, Ecuador, El Salvador, Guatemala, Honduras, Peru, and Kenya. The research at these locations generally complemented projects being carried out for Utah farmers under the Utah Agricultural Experiment Station program. Funds, however, were provided by the US Agency for International Development as part of their War on Hunger program with supplemental funds in some cases being provided by the governments of the countries where the research was in progress. Some of the research work in Latin America will be summarized to illustrate how the process has functioned.

A. A. BISHOP, G. H. HARGREAVES, and E. C. OLSEN, III

IRRIGATION: BASE FOR DEVELOPMENT
Irrigation Research Technology

The need for a research and demonstration tool to show and measure the effect of various amounts of water on plant growth led to the development of what is called a point-source, continuous-water-variable procedure. In this technique, water is applied from a single sprinkler head with maximum water applications near the sprinkler tapering to zero at the periphery of the circle of coverage. The effect of adequate water versus drought is easily seen in a single plot (Figure 1). By dividing the circle into pit-shaped wedges, and applying fertilizer treatments, the interactions among fertilizers and water, and crop responses become visible and measurable (Figure 3). The maximum treatment for the corn is obviously the highest point on the figure.

The line-source, continuous-water-variable, a variation of the point-source technique, was jointly developed in Utah experimental farms and project farms of El Salvador. Instead of water being applied from a single source (one sprinkler), a line of sprinklers is used (Figure 2). The water applications vary from a maximum along the line to zero at the far reach of the sprinkler jet. Again, the results of adequate versus inadequate water can be easily observed on a single plot. Note the taper in the height of the corn crop away from the line source in the two photos, one taken in Logan, Utah, and the other in El Salvador. Line-source irrigation requires more land but is more easily managed and the statistical analysis is less complicated than with a point-source system.

The continuous water variable research techniques are an outgrowth of our international work and constitute a powerful new procedure for experimental plot work such as the variable water applications being used and studied at Logan, Kaysville, and Huntington. They are even being used to solve problems related to energy development in Utah. The optimum water applications for different fertilizer rates can be easily established using this technology.

Evapotranspiration and Dependable Rainfall

On-farm water management research at Utah State University and in numerous developing countries has emphasized how availability of water and climate in general influence productivity. Efficient on-farm water management, including rainfed and irrigated agriculture, requires knowledge of how water availability relates to agricultural production. Yields (or productivity) and the economics of agriculture depend on soils, fertility, and other climatic parameters, however, as well as on management.

Several new ideas on water availability developed as a result of the local and overseas work have been experimentally evaluated and introduced to farmers. An improved method was developed for estimating potential evapotranspiration (ETP) and irrigation requirements. Most currently used methods for predicting crop water needs are site-specific and require local calibration. The method developed by Hargreaves (1,2) appears to be simpler and more general, as well as more reliable and accurate while requiring less data than most other estimating methods. It can be used directly by Utah farmers interested in refining their irrigation water management procedures. The same procedures are used in developing countries for project planning and water management. The new method is a simple-to-use equation:

\[
ETP = 0.0075 \times RS \times T^*F
\]
TABLE 1. Climate and the Water Balance for Salt Lake City

<table>
<thead>
<tr>
<th>Salt Lake City, Utah USA</th>
<th>El. = 1288</th>
<th>Lat. = 40 46 N</th>
<th>Long. = 111 58 W</th>
<th>KS = 10.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM 34</td>
<td>30</td>
<td>40</td>
<td>45</td>
<td>36</td>
</tr>
<tr>
<td>PMI 4</td>
<td>3</td>
<td>3</td>
<td>11</td>
<td>0</td>
</tr>
<tr>
<td>P79 17</td>
<td>15</td>
<td>18</td>
<td>27</td>
<td>10</td>
</tr>
<tr>
<td>P60 27</td>
<td>24</td>
<td>28</td>
<td>36</td>
<td>23</td>
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<tr>
<td>PMX 80</td>
<td>82</td>
<td>93</td>
<td>125</td>
<td>86</td>
</tr>
<tr>
<td>TMC - 2.1</td>
<td>6</td>
<td>4.7</td>
<td>9.9</td>
<td>14</td>
</tr>
<tr>
<td>HM 74</td>
<td>69</td>
<td>56</td>
<td>48</td>
<td>44</td>
</tr>
<tr>
<td>S 49</td>
<td>55</td>
<td>64</td>
<td>67</td>
<td>73</td>
</tr>
<tr>
<td>PD 19</td>
<td>17</td>
<td>20</td>
<td>29</td>
<td>13</td>
</tr>
<tr>
<td>ETP 0</td>
<td>0</td>
<td>62</td>
<td>97</td>
<td>142</td>
</tr>
<tr>
<td>ETDF - 19</td>
<td>-17</td>
<td>42</td>
<td>68</td>
<td>130</td>
</tr>
</tbody>
</table>

MAI .32 .30 .09 .04 .02 .03 .03 .19 .47

<table>
<thead>
<tr>
<th>Heading</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM</td>
<td>Mean monthly precipitation in mm</td>
</tr>
<tr>
<td>PMI</td>
<td>Minimum monthly recorded precipitation (30 years)</td>
</tr>
<tr>
<td>P79</td>
<td>The 79 percent probability of precipitation occurrence</td>
</tr>
<tr>
<td>P60</td>
<td>The 60 percent probability of precipitation occurrence</td>
</tr>
<tr>
<td>PMX</td>
<td>Maximum monthly recorded precipitation</td>
</tr>
<tr>
<td>TMC</td>
<td>Mean monthly temperature in degrees Celsius</td>
</tr>
<tr>
<td>HM</td>
<td>Mean monthly percent relative humidity</td>
</tr>
<tr>
<td>S</td>
<td>Percentage of possible sunshine</td>
</tr>
<tr>
<td>PD</td>
<td>Dependable precipitation—The 75 percent probability of precipitation occurrence</td>
</tr>
<tr>
<td>ETP</td>
<td>Potential evapotranspiration (ETP = 0.0075 x RS x T°F)</td>
</tr>
<tr>
<td>ETDF</td>
<td>Potential evapotranspiration Deficit (ETP-PD)</td>
</tr>
<tr>
<td>MAI</td>
<td>Moisture Availability index (P/D/ETP) Equation 7</td>
</tr>
</tbody>
</table>

in which ETP is the maximum potential water used by a crop during one month, RS is incident solar radiation in equivalent depth of water evaporation in the same units as ETP and T°F is mean monthly temperature in degrees Fahrenheit.

A moisture availability index, MAI, was also developed to evaluate rainfall dependability and adequacy for agriculture. The MAI is the amount of rainfall with 75 percent probability of occurrence (PD) divided by the ETP (MAI - PD/ETP). In the tropics the overall effectiveness of the rainy season for agriculture and for forest and range production is directly correlated with the number of months having a MAI of 0.34 or above. The same approach can be used to evaluate the potential productivity of dryland areas. Values of MAI of 1.33 or above correlate well with drainage requirements and benefits to be derived from surface drainage.

A classification of climate for use in agricultural technology transfer was developed as a result of in-state and overseas work. The new classification divides climate into types using mean monthly temperatures as the criterion. Climates are further classified (according to the number of months having MAI values in predetermined ranges) into divisions ranging from very arid to very wet. These are also relatable to dry land agriculture.

Considerable effort has been given to developing water-related crop production functions and measuring the effect of fertility-water-ETP interactions on crop production. The methods developed have been adapted for use by other US universities and several inter-
national agricultural centers. For example, it has been found that alfalfa requires about six inches of water per ton, no matter what the climate. If more water than this is applied, it is probably being wasted.

Hargreaves (3) combined the three concepts presented above in a publication showing global climatic classifications and the water balance values and related the concepts to agricultural production. This world-wide study, which includes Utah and the Mountain West, has been recently reviewed by IRRINEWS (4) and is being used internationally for planning water resource developments and numerous studies related to other economic development projects. Table 1 presents a typical water balance computation which includes the climatic data. Reports presenting detailed country-wide evaluations of water requirements and the water balance using monthly rainfall have also been completed for a dozen Latin American countries and a nine-state area of Northeast Brazil.

Drought-Proofing

The benefits that can be obtained from drought-proofing by off-season irrigation are illustrated by conditions that exist in the Aconcagua Valley in north central Chile. In that valley, under normal conditions, there is insufficient water available for crop growth from October through June. The principal irrigation water supply is the Aconcagua River, which provides about 23,500 acres with a permanent water right, and provides water to an additional 5,500 acres when excess water is available.

During the drought year 1968-69, only about 50 percent of the irrigated land received water and yields were reduced by about 25 percent. Except for deep-rooted perennial crops such as alfalfa and peaches, no off-season irrigation was practiced to store moisture in the root zone even though some surface and groundwater supplies went unused during the off season. Unused surface waters could have been used to fill the root zone during the prior autumn and winter seasons so that the soil moisture reservoir use was optimized. It is immaterial to plants whether the moisture they need was placed in the soil several months before or just before it is required.

Soil moisture conditions for drought-proofing could be improved, however, by practicing off-season irrigation. If the soil moisture stored in the root-zone in July at the beginning of the crop year is at full capacity, maximum benefit can be obtained from the available stream flow. With a full, normal cropping pattern, there is still insufficient surface water available after December (summer in Chile). Therefore, if supplemental pumping from groundwater is practiced from December through June, sufficient water can be maintained for crop growth throughout the growing season, and the soil moisture can be brought up to its maximum desirable off-season condition by the end of the crop year in June.

A drought-proofing alternative to supplementary pumping is to change the cropping pattern. In this case the irrigated forage can be reduced from 40 to 15 percent of the cultivated area while the remainder of the cropping
pattern is unchanged. Sufficient water is then available through the full year without pumping, but little available moisture remains in the soil for a carry-over into the following year. If the drought lasts for only one year, which is typical, this would cause no problem.

The cost of developing and maintaining a pump installation for an infrequent drought year makes it advisable to seek ways to improve water use efficiency. This can be achieved by one or more of the following: reducing seepage in the distribution system, improving the canal maintenance, imposing better regulation and control on water delivered to the farmers, and improving irrigation practices. A small gain in one or all of the above should result in an increase of the overall water use efficiency.

In the Aconcagua Valley, a higher efficiency, in conjunction with off-season use of all available river water, allows the soil reservoir to be at its nearly full level by 31 cm at the beginning of the crop year in July. With this management, water is essentially sufficient throughout the drought year, but the soil moisture is completely depleted by the beginning of the next year.

The ideas utilized in this study in Chile are essentially those practiced in Utah under good irrigation management conditions and in dry farm situations. The soil moisture reservoir is used to store water from fall irrigation or winter precipitation for later withdrawal in the crop-growing season. The Utah water management concept was applied to the Chilean drought condition. The refinements developed for Chile can now be recommended in all areas of Utah during water short years, especially in areas with no storage reservoirs for regulating stream flows that are subject to the same vagaries of stream flow as in the Chile case.

Water Management Synthesis

To fulfill the most recent international water research contract, the Department of Agricultural and Irrigation Engineering will make a detailed study of irrigation projects around the world to obtain information concerned with the art and science of both modern and primitive irrigation practices. It has already been determined that traditional irrigation in some countries, although highly labor intensive, may be as efficient as the modern sprinkler and trickler, energy- and capital-intensive systems of the developed world.

Under the current international contracts, department personnel will also be studying land preparation (land leveling), water scheduling, water distribution, water lifting devices (pumps), both motorized and human powered, irrigation organizations, water course improvement, and extension methods for irrigation information. This comprehensive study of irrigation around the world is certain to bring to light additional techniques and innovations that can be used by Utah irrigators as they approach a future involving high energy costs and water shortages.

REFERENCES


ABOUT THE AUTHORS

A. A. Bishop is Emeritus Professor and former Department Head in the Agricultural and Irrigation Engineering Department.

G. H. Hargreaves is Research Engineer in the Agricultural and Irrigation Engineering Department.

E. C. Olsen III is Director, International Irrigation Program and Associate Professor in the Agricultural and Irrigation Engineering Department.
Seminars and workshops are held in various countries to explain the INFIC System of Naming and Analyzing Feeds. Dr. Lorin E. Harris went to Kenya to give a seminar to this group.

Dr. Lorin E. Harris explains how to determine cell walls in feed samples to a student in Bolivia.

Washing of treated rubber seeds (through ash or hot water soaking) in order to remove hydrocyanic acid after hydrolysis of cyanogenic glucoside which is contained in rubber seeds. This process renders the seeds edible and not poisonous for animals. The seeds were produced in Liberia.

Using the animals' nutrient requirements and the nutrients in each feed, the amount of each feed for a ration mixture is calculated. Here the feeds are being mixed together by hand.

Sheep are fed individually on the range to determine nutrient requirements under range conditions.
In any country, improvements in the animals themselves can be optimized only if the animals receive adequate diets. But in much of the undeveloped world, feeds are often in short supply, and what is available has rarely been analyzed as to its nutrient composition (Table 1). The difficulties are compounded by the prevalence of non-standardized descriptive terminology used in describing the available feeds.

A cooperative project therefore was implemented in 1963 under the supervision of the US National Institute of Health, the US National Academy of Sciences, and Canada Agriculture. E. W. Crampton of Canada and L. E. Harris of Utah State University were the project leaders for Canada and the United States.

In 1968, L. E. Harris proposed an International System for Naming Feeds (Harris et al. 1968). He called the system to the attention of the Food and Agricultural Organization of the United Nations (FAO) in the late 1960s. In 1971, FAO called a meeting of interested scientists and encouraged international cooperation in describing feeds and gathering feed nutrient information designed especially to assist those people living in developing countries.

An International Network of Feed Information Centers (INFIC) was organized by individuals from countries involved in developing feed information services (INFIC 1978). The system of describing feeds and of processing feed information with computers that came from the US-Canadian project was developed into an International Feed Nomenclature by INFIC. There are now INFIC Centers in Australia, Canada, France, Germany, Syria, Ethiopia, Costa Rica, Malaysia, Philippines, South Korea, and the United States (Figure 1).

The International Feedstuffs Institute (IFI) was formed at Utah State University to represent the United States on an international level. In 1974, USAID (within the Department of State) contracted the services of IFI to assist countries of Latin America, the Middle East, and Southeast Asia in a feed information project. The US Department of Agriculture also contracted with IFI in 1978 to accumulate and generate feed information for United States feeds with emphasis on obtaining presently unknown nutrient information. IFI is the INFIC Center for the United States which correlates the technical phases of the total network of world Centers.

International Feed Description and International Feed Names

Nutrient information on feeds described by the International Feed Description is linked by a five-digit international feed number (IFN) with the same feeds produced in other regions of the world. The feed name and information can then be translated into any language with computer programs. A concise, short, popular "International Feed Name" is used for all countries.

An international vocabulary of feed terms for describing and classifying...
feeds was agreed upon (Harris et al. 1980). This system uses combinations of terms that describe six characteristics of feeds. These are called facets (origin, part, process, maturity, cut, and grade) (Table 1).

Animal Feeding Systems

Feed nutrient information indicates the relative value of a potential feedstuff which, of course, does not guarantee that animals will consume the product in sufficient quantities to benefit them, nor that the product is safe to be fed to animals destined for human consumption (Figure 2). Feeding trials must be controlled to demonstrate the value of any potential feed ingredient. Ingredients are tested by substituting the questionable product for equal amounts of nutrients provided by a proven feedstuff and observing feed intake, animal growth, reproduction, milk production, etc. (Figures 3 and 4). Further studies can determine what combinations of ingredients, among those available within a specific country, will maximize animal production. Basic information on the feed's nutrient content and on the animals' nutrient requirements (to maintain themselves, gain weight, and/or to produce products such as milk, eggs, and wool) guides the planning of feeding experiments. Only research done with the species, breeds, types of animals, and feeds that are common to a particular region can be used to develop feeding recommendations for use by farmers in these areas (Figure 5).

An example of a feeding system for swine being raised in the tropics is outlined in Table 2. For maximum performance, the bananas should be ripe and yellow. This increases consumption and performance.

Maximizing Animal Production Profits

The function of management (large or small) in any animal production system is to maximize profit. To achieve this; it is necessary to know the relationship that exists between the value, in economic terms, of the product compared to the costs of its various inputs. The output is measured in terms of the amount of product available for sale. The inputs are many and include such items as cost of feed, housing, veterinary expenses, capital outlay, and labor. By expressing this relationship in the form of an equation, it is possible to assess with some degree of accuracy which combination of these factors will result in the maximum amount of profit. Computer software has been developed to perform these computations.

The steps needed before the final solution (diets and other information) can be calculated by the computer are illustrated in Figure 6. An extension specialist can sample and chemically analyze the feeds available on a farm for their nutrient composition. Additional nutrient information can come from feed composition tables compiled by IFI. After the nutrient value of the feeds has been determined, the daily nutrient requirements of the animals to be fed must be estimated according to the production expected (meat, milk, eggs, fiber, work). Figure 7 illustrates the apparatus necessary to determine digestion coefficients and metabolizable energy for sheep grazing range plants. Information thus acquired is available in several publications including the National Research Council, Nutrient Requirement Series (USA) and the Agriculture Research Council (UK) publications. IFI has compiled the feed composition tables for the National Research Council for the United States since 1963.

 Usually, the economic value per unit of nutrient (protein, energy, etc.) required must also be known when formulating the optimum diet for maximum profit from a feeding operation. The computer can then be used to make the computations. The resultant dietary information is then forwarded by the livestock specialist to the ultimate user, the farmer. The first time these procedures were put into effect in a 2,500 head feedlot the savings were $140 per day or $51,000 per year.

Many developing countries are applying these procedures to increase their production of animal products. Starting in 1975, USU personnel traveled extensively in the Middle East, Latin America, and Southeast Asia collecting data on the nutrient values of feeds. The Arab and Middle East Tables of Feed Composition (Kearl et al. 1979) were prepared using that information and have been distributed to 25 Arab and Middle East countries. Similarly, 21 Latin American countries are now using the information contained in the Latin American Tables of Feed Composition (McDowell et al. 1974). Tables of Feed Composition for Indonesia (Hartadi et al. 1980), Philippine Tables of Feed Composition, and Southeast Asia Tables of Feed Composition will soon be available.

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**TABLE 1. An International Feed Description and an International Feed Name**

<table>
<thead>
<tr>
<th>Item</th>
<th>Feed Description</th>
<th>Feed Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Genus</td>
<td>Medicago</td>
<td>Medicago</td>
</tr>
<tr>
<td>Species</td>
<td>sativa</td>
<td>sativa</td>
</tr>
<tr>
<td>Common name</td>
<td>Alfalfa</td>
<td>Alfalfa</td>
</tr>
<tr>
<td>Part</td>
<td>aerial part</td>
<td></td>
</tr>
<tr>
<td>Process</td>
<td>sun-cured</td>
<td>sun-cured</td>
</tr>
<tr>
<td>Maturity</td>
<td>early bloom</td>
<td>early bloom</td>
</tr>
<tr>
<td>Cutting</td>
<td>cut 1</td>
<td>cut 1</td>
</tr>
<tr>
<td>Grade</td>
<td>17% protein</td>
<td>17% protein</td>
</tr>
<tr>
<td>IFN</td>
<td>1-12-376</td>
<td>1-12-376</td>
</tr>
</tbody>
</table>

Aerial part + sun-cured is equivalent to hay

The number one in front of the International Feed Number (IFN) indicates that this is a class 1, Forage and Roughage feed.

**TABLE 2. A Feeding System for Swine, Using Bananas**

Growing and Finishing

- Bananas with peelsings free choice
- 30% well-balanced protein supplement
- Gain 770 to 830 g/day
- Feed/kg gain 3.4 to 3.5 kg
- For pigs 18 to 90 kg in weight use a protein supplement in automatic feeder. Pigs will eat 830 to 850 g per day. Also feed 900 to 950 g bananas per day.
- Pre-gestation and Gestation
- Feed 1.8 kg of a 16% protein corn-soybean ration.
- Or feed 5.0 to 5.2 kg ripe or green bananas with 700 g of a 40% protein supplement.
- Lactation
- Most difficult problem in life cycle.
- Feed 5.5 to 6 kg/day of a 16% protein ration. This is equivalent to 20 kg bananas.
- Or feed 10 kg bananas and 2 kg of a 20% protein supplement.
In 1980, USU personnel visited nine Arab and Middle East countries to gather information on nutrient requirements of goats, sheep, and cattle in these areas. The resultant publication on Arab and Middle East Feeding Standards for Ruminants will be completed in the near future. By using data from research conducted in this region using indigenous species of animals, the publication will give Arab and Middle East agriculturists directly applicable information on their animals' nutrient requirements. As this information becomes widely used, production of meat, milk, and fiber will increase.

The overall impact of USU research on international livestock and feed production may never be measurable. To whatever degree the results allow people in the developing world to help themselves toward an adequate level of nutrition will benefit all of us. Debilitating malnutrition and starvation anywhere in the world is morally intolerable and must eventually depress standards of living everywhere.

REFERENCES

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International Network of Feed Information Centers. 1978. Publication 1. Prepared on behalf of INFIC by the International Feedstuffs Institute, Utah State University, Logan, Utah, USA 84322.


FIGURE 6
The system to provide the farmer or feed dealer with the most profitable diet formula begins by having the farmer or feed dealer submit feed samples to the chemical laboratory. Data from this sample, together with book data and animal requirements, goes to the Extension Specialist. He in turn puts the data in the computer, which calculates the most profitable diet. This formulation is given to the farmer or feed dealer through a remote terminal, over the phone, or by letter.

FIGURE 7
Dr. Lorin E. Harris (with hat and glasses) is instructing students in Pakistan on how to determine the digestibility and metabolizable energy of range plants with native Pakistan sheep.

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P. V. Fonnesbeack is Research Assistant Professor in the Animal, Dairy, and Veterinary Sciences Department.
FIGURE 1. When the caatinga woody vegetation is cleared, a lush growth of herbaceous species occurs. Perennial grasses can be established under these conditions and forage production multiplied many times.

FIGURE 2. Perennial grasses demonstrate prodigious growth in northeast Brazil in experimental plots where the caatinga has been cleared. African grasses in the genus Cenchrus may be the key to the future of livestock production in the region.

FIGURE 3. In this photo you can just make out the top of USU's Dr. John Malechek's head, not too far away, an indication of the thickness of the vegetation understory.

FIGURE 4. Dr. Malechek with Dr. Luis Vali, of Brazil's national sheep and goat research center in Sobral, inspect the length of current season's growth on Leucaena leucocephala, a promising legume for the tropics.

FIGURE 5. A Borana beauty laughs coyly at being photographed as she tends her husband's camels.

FIGURE 6. A herder tends his flock in the foothills of the Atlas Mountains in Morocco.

FIGURE 7. Tribal women herd family cattle to an enclosure for the night.

FIGURE 8. Camels are still a major mode of transporting goods and people in this region.
RANGELANDS: A FRONTIER IN DEVELOPMENT
THE SUCCESS OF A MODERN FARMING PROJECT has become largely a function of machines and chemicals, and can be defined in terms of conventional economics. In a pastoral system dependent on natural forage resources, however, the problems are not so easily solved by technology, and the ecological factors limiting production are intertwined in a complex of cultural traditions. Drilling permanent wells in a desert discourages nomadic movement and primes the range for overgrazing in an average year and high livestock mortality by starvation during the next drought. Likewise, disease control and other veterinary services allow livestock numbers to increase and perhaps trigger another round of devastation unless incentives for greater offtake are generated commensurately.

Even if forage and water supplies are improved and attractive marketing systems provided, the pastoralist may prefer to snub the lure of monetary gain, and nurture his growing herd with the dedication of a Wall Street broker cultivating the natural increase of an investment portfolio. And when he decides to sell some animals, he may elect to trek them to market in a neighboring country.

One way to view such circumstances is as a challenge to realize the tremendous potential for livestock production and financial dividends that could be derived from improved management of rangelands that now provide mere subsistence. In the tradition of a Land Grant School, USU's involvement is in the form of education, cooperative research and demonstration, rather than development per se.

Brazil
Some of the snags associated with international projects are more literal than metaphorical. The northeast corner of Brazil is covered by caatinga—dense scrubby vegetation 15 to 30 feet high that is almost impenetrable. The 12 million peasants who live in the region depend for their livelihood on subsistence crops and on sheep and goats that can forage among the thorny twisted branches. The vegetation is not very suitable for cattle. In the six-month dry season, the caatinga loses its leaves and the livestock suffer severe nutritional stress. Several Range faculty from USU, led by John Malechek, are working with scientists at the Brazilian national sheep and goat research institute (Centro Nacional Pesquisa en Caprinos) at Sobral, in the state of Ceara, trying to design management practices for rangeland and small ruminants that will benefit the peasants.

With funding from US/AID under the Title XII Collaborative Research Support Program, the team is working on three fronts: describing the annual diet cycle and its nutritional characteristics; exploring the application of satellite imagery to survey the vegetation of the area and assess potential productivity; and manipulating the caatinga to generate more useful forage. Under normal conditions, dry season fuel is not concentrated enough to carry a fire in the caatinga, so the accepted approach to land clearing has been laborious handwork. If perennial grasses can be established in place of tall scrub, however, the mix of grasses, forbs, and shrubs can probably be controlled by a combination of fire and grazing treatments, and initial experiments by Brazilian scientists indicate that such manipulation could allow livestock carrying capacity to be multiplied 10 to 15 times! Introduced forage species show promise for overcoming the nutritional problems.

Bolivia
On many ranges in developing countries, the grazing animal itself (rather than fire, chemicals, tractors, or exotic species) is the key to improving production. On the Altiplano of Bolivia, USU's Karl Parker set out some wire cages in 1972 on natural pastures that had been kept grazed to about one-inch height by llamas and alpacas. Parker's goal was to find ways to reduce the excessive erosion he observed throughout the Altiplano. After several growing seasons, the forage inside his cages stood nearly four feet high, demonstrating far greater growth potentials than had been originally expected. Simultaneously, what had been predominantly a forb plant community was changing over to perennial grasses. While in Bolivia, Parker trained extension workers and technicians, established a national range herbarium in LaPaz, and tested mechanical techniques for renovating Bolivian rangelands. His primary legacy, however, was a strategy of controlled grazing which was later adopted by a World Bank project.

Morocco
Since range development projects often lie among the underprivileged of AID programs, a range manager has to be resourceful. Take the case of Range Professor Jim O'Rourke. Before the US Naval Base at Kenitra, Morocco, was closed in 1978, staff at that country's AID mission were given an opportunity to salvage equipment that would otherwise be sold as scrap. With a couple of large trucks borrowed from the Hassan II Institute of Agronomy and Veterinary Medicine, and a couple more rented, O'Rourke's convoy spent three days hauling 13 truckloads of refrigerators, desks, filing cabinets, etc., and enough barbed wire to string 30 km of five-wire fence. Morocco had a fully equipped range laboratory almost overnight.

In those days O'Rourke was on an AID project in cooperation with the University of Minnesota, selecting potential Moroccan Range faculty for training in the US, guiding their research programs and providing support facilities. He also acted as an itinerant extension worker, travelling throughout the countryside and developing a love for it. Now on the USU staff, O'Rourke expects to be back in Morocco soon to establish a Title XII-funded project that will follow the pattern of cooperative research described above for Brazil. He will also initiate a range extension project demonstrating better range and livestock management to peasant-level herders at five locations in the lee of the Atlas mountains while maintaining a teaching role at Utah State University.

Sudan
The town of Kadugli may have about the same population as Logan, but none of the streets are paved, about the only vehicles sighted belong to the govern-
ment, and the houses are thatched adobe dwellings. The nearly 30 inches of rain during the summer create a subtropical humidity.

Within a week of finishing his doctoral dissertation in 1980 under Dean Box of the College of Natural Resources, Trent Bunderson and his new bride were off to the community of Kadugli in Southern Kordofan Province of the Sudan. With a loan from the World Bank, and contributions through US/AID, and from its own treasury, the Sudan is undertaking a project to integrate crop and livestock production in the western part of the country. Bunderson's initial objective is to inventory the major vegetation and soil types of the region, assessing potential forage production and describing the extent of overgrazing. He will also inquire into the implications that nomadic grazing and periodic burning have for these savannah range ecosystems.

When the wet season begins, the herdsmen move their cattle to drier country further north, apparently to escape the mud and flies. During the dry season they drift back seeking water and forage, but stay around Kadugli for only about three months before resuming the cycle of transhumance. Bunderson hopes to develop a management program involving grazing systems and forage storage that will allow the cattle to stay near Kadugli year-round, thus improving chances for increasing forage harvests. At the moment, 95 percent of the area's livestock are kept for subsistence, so a marketing and transport system to deliver any increased production to consumer centers and export points will need to be established. Such a development program will require changes in the traditional ways of the nomads if it is to succeed. Recognizing the importance of cultural factors, the range and livestock efforts are being integrated with sociological research to help understand how to help the pastoral peoples make their necessary adjustments.

Project management for the range aspects of this Sudanese program is handled by Washington State University, but the USU's Range Science Department Chairman, Don Dwyer, is the range consultant on the project. He has had considerable influence on design and implementation. Bunderson's Sudanese counterpart, Abdullah Suliman, received his MS at USU, as did the principal project officer from the Sudanese Ministry, Ali Darag.

**Education**

The policy of the USU Department of Range Science is to emphasize the major contribution education can make to international development. Students from eight countries are enrolled in the department's baccalaureate program; foreign graduate students either enrolled or accepted into the department represent 15 countries and compose about one-third of our graduate students. Just a few years of study and guidance under the USU range staff can have an impact on range management in the student's home country that lasts for his/her professional lifetime.

One of our educational concerns has been the extent to which a college curriculum designed for Americans is appropriate for a foreign student who will be applying his knowledge in a totally different biogeographical region and in the context of different social, cultural, and political systems. The department therefore has generated courses that focus on range management in developing countries, with particular attention given to understanding the planning, implementation, and evaluation of range/livestock aid projects. These courses complement the traditional curriculum while giving foreign students a more relevant degree. They also prepare Americans who want to work overseas with a "conversion kit" of conceptual and ecological perspectives.

Range faculty have also assisted with curriculum counseling and reviews at overseas institutions. In 1978, Don Dwyer and Thad Box appraised the needs of Kenya for Range Management education, and suggested curriculum revisions or innovations at two diploma schools and at the University of Nairobi. Department personnel are currently involved in perfecting a proposal to establish a Range Science Department at the University of Somalia. An appropriate syllabus has been recommended for introducing range management into the Somalia secondary school system.

**Professional Services**

A dimension of the department's international involvement that bears a low profile but is of great significance can be exemplified by the activities of Cy McKell. In 1980, McKell led a National Academy of Sciences panel on a tour of a stressed region in western Senegal to devise strategies for increasing the ecological and agricultural productivity of the groundnut basin. He also has a continuing role as a chairman of an NAS panel concerned with New Plants for Arid Lands, which recently has been active in Egypt.

These advisory committees exercise counsel at the highest levels of government in a developing country, and help shape the future of aid programs. The challenge that McKell cites as particularly exciting is problem analysis of semi-arid lands that do not support traditional agricultural practices. His major contribution to solving such problems is the introduction of multiple-use fodder shrubs that help stem desertification trends and enhance wildlife habitat while providing more valuable year-round forage. Results of experiments conducted at the UAES field station near Nephi, Utah, are being reflected in the research programs at stations in Syria and Kenya, where the benefits of shrubs in semi-arid rangelands are being studied.

Over the past two decades USU range scientists have occasionally undertaken international assignments on a more or less ad hoc basis. In the last two years, however, with encouragement from Title XII, these efforts have been solidified into a structured program with defined objectives and procedures. This new international dimension represents a concerted effort to help transform rangelands in less developed countries from subsistence resources in a state of degradation into a productive and reliable component in each nation's economy.

**ABOUT THE AUTHOR**

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IN TODAY’S WORLD, approximately 70 countries can be classified as less developed (than the US, Europe, etc.). The majority of the people living in these less developed countries (LDCs) are malnourished, with a perpetual shortage of high quality protein, making them subject to early death, debilitating fatigue, and disease. Lasting solutions to such misery can come only as the prevailing health status improves and the people have enough resources to help themselves by increasing food production.

Since balanced, high quality protein is such a crucial need in the LDCs and is most easily obtained from animal products, members of Utah State University’s International Sheep and Goat Institute have concentrated their efforts toward improving meat production in various LDCs. The countries obviously differ in their traditions as well as agricultural potentials, so each research project has had to be designed to accommodate these differences. In some areas, for example, poultry and swine are well adapted and preferred by the people. In others, especially in the Middle East, parts of Africa, and South America, sheep and goats are the choice.

Whatever the animal or bird in question, however, there generally are two effective ways to increase productivity. One uses hybridizing between breeds or types, or other

FIGURE 1. The American Suffolk, probably the largest breed in the world, was imported to Iran to improve reproduction, growth, and body size in native sheep.

FIGURE 2. The Greek Chios is noted for its milk production and high reproductive rate.

FIGURE 3. On the right is the native Ghezel sheep; in the middle, the Suffolk-Ghezel cross; on the left, the Greek Chios-Ghezel cross. The Suffolk-Ghezel proved to be the most successful.

FIGURE 4. All native Iranian sheep (except one minor breed) are descriptively referred to as fat-tails. This pendulous tail was thought to have been developed in the past to provide a source of animal oil, but today it is thought of as an impediment to breeding.

FIGURE 5. The Israeli Awassi, a milking breed of fat-tailed sheep, were crossed with the German Merino and Finland’s Finn sheep to produce offspring having a high reproductive rate and improved growth rate.
DEVELOPING COUNTRIES

gerenetic procedures to increase vigor. The other involves manipulating (through hormones and/or nutrition and other environmental factors) reproductive rates. The Utah State University researchers have been trying both approaches, with the emphasis on sheep varieties, which are adapted to practically every environment where human societies exist and which produce not only meat and milk, but fabric-making fiber as well. Another major thrust has been concerned with the feeds used to sustain these animals, and with the documenting of nutritive values and the standardizing of both data and descriptive terminology.

Sheep Production

In places such as the highlands of Bolivia and Peru, the mountains and deserts of Middle East countries, and in some tropical and semi-tropical areas of Mexico and Africa, sheep can live and produce food for human beings on lands that would otherwise contribute little to human diets. The animals add meat and often milk to the limited food supply in these countries, and their wool or hair is needed for making clothes, carpets, and tents.

Typical of the work being done by personnel of Utah State University's International Sheep and Goat Institute, is a research program started in Iran in 1973. Using funds from an Iranian ministry, the researchers were to define practical ways that meat production by sheep could be increased in that country.

The research in Iran continued until December 1978, when it was interrupted by the political revolution. During that five-year interval, six scientists and two technicians lived in Iran for one to two years each. The scientists were James A. Bennett, Thomas D. Bunch, Brannick Riggs, J. Juan Spillett, Thomas Cox, and Paul Daniels. Russell Madsen and Owen Degg served as technicians. Several consultants were also involved. Those from Utah State University were Doyle J. Matthews, Jay W. Call, and Darrell H. Matthews; Warren C. Foote coordinated the project and acted as a consultant. The principal cooperating Iranian scientists were Mohammad Mashhoon, Hessa Taleghani, Mustafa Djerari, and Kazem Mashhoon.

The prime challenge was the need to develop genetic types of sheep that would be suited to confinement or semi-confinement under Iran's hot, dry environment. To optimize the management of the "new" sheep, political/social/traditional restraints would have to be modified. Since it would be virtually impossible to change the habits of Iran's nomadic tribes (whose sheep harvest what forage manages to grow on the country's ranges and wastelands) one solution to the problem was to develop a sheep capable of improved production under more intensive management. In addition, sheep would be purchased from the nomads and finished more efficiently under the more intensive production programs. Under the anticipated system, better use could be made by the sheep of crop residues and food manufacturing by-products.

The search for sheep that would be efficient producers under a confined management system began with the 18 breeds native to Iran. Several years were required to determine the reproductive and productive potentials of the native breeds. At the same time, American Suffolk and Greek Chios rams (Figures 1, 2, and 3) were imported as a basis for hybridization tests.

The American Suffolk is probably the largest breed of sheep in the world, with an enviable record in terms of reproductive performance, growth rate, and meat quality. The Chios is well known for its milk production and for high reproduction rate. Among the first native breeds tested were the Ghezel and the Baluchi. Later a small flock of approximately 25 Chios ewes and rams were imported directly from the Island of Chios in Greece to Iran and additional Suffolk rams and also Targhee rams were imported from the United States. All of the Iranian native breeds of sheep are descriptively known as fat-tails (Figure 4), with the exception of a minor breed near the Caspian Sea. The tail of members of these breeds becomes very large and pendulous and can be a physical barrier to breeding.

To insure breedings between the imported rams and the native, fat-tailed ewes, we often had to use artificial insemination. Work done in Iran during the late 1950s and early 1960s (primarily by professors Hyrum Steffen and Milton A. Madsen from Utah State University) had shown that the problem-making tails could be humanely removed by using a rubber band or elastator at the time of birth. All female lambs born during the 1970s study were docked by this method to facilitate their later breeding and hopefully to improve production efficiency.

In addition to increased production by crossbred versus the straight-bred native sheep (Tables 1-3), the 1970s research led to several management innovations. These included animal health programs, removing the tail of each ewe lamb at birth, selection of breeding animals, time of breeding, care at lambing, improved nutrition, facilities, and methods of handling animals.

Increases in meat production that could be expected from proper applications of the research data were estimated. Although the work was incomplete in some aspects because of the political revolution, we were able to demonstrate that the level and efficiency of meat production by sheep in the Middle East could be increased as much as 80 percent by modifying genetics and management. An important adjunct to the breeding program had sheep produced under nomadic range conditions brought to our newly created semi-intensive or intensive production units to be finished for slaughter.

In Israel, beginning in 1975, similar studies were undertaken on a smaller scale with funds from the USA/Israeli Bi-national Science Foundation. Males of the Finn sheep from Finland and the Romanov (originally from Russia but imported to Israel from France) were crossed on females of the native Israeli Awassi, which is primarily a milking breed of fat-tailed sheep, and of the meat-producing German mutton Merino.
The Awassi and the German mutton Merino are relatively large breeds of sheep and the Awassi is particularly well adapted to the semi-desert and desert environments of Israel. The Finn sheep and the Romanov are breeds with very high lambing rates with some potential to lamb more than once per year. The progeny of these crosses (Figure 5) have a high reproductive rate, and improved growth rate and pelt.

This research project, as had been the one in Iran, was geared to intensive or semi-intensive management systems that could utilize the country's relatively large amounts of by-product feeds. Conducted primarily at the Gilat Experiment Station near Be' er Sheba and at the Bet Dagan Experiment Station near Telaviv, the research was cooperative among Warren C. Foote from the USU International Sheep and Goat Institute, and Henry Goot, Ezra Eyal, and other Israeli scientists. The crossbreeding produced offspring with markedly improved reproduction and growth rates (Table 4). Lamb comparisons showed few differences between the four genetic combinations, the Finn sheep or Romanov X the mutton Merino or the Finn sheep or Romanov X the Awassi for either the F1 or F2 generations (Goot et al. 1979 and 1980). The new genetic types, particularly the crosses between the Finn sheep and the Awassi quickly became popular among sheep producers in Israel.

A just-approved three-year grant from the USA/Israeli Bi-national Agricultural Research and Development (BARD) Fund extends the contract and will allow us to confirm data and develop better management and breeding systems. The International Sheep and Goat Institute is also working with the Ezra Taft Benson Food and Agriculture Institute to develop training and demonstration programs in Israel to help Israelis apply the research results.

Environmental Effects

Reproductive processes in sheep are influenced by the hours of daylight per 24-hour period. For example, breeds developed near the equator (where daylight hours are relatively stable year-round) have a longer than average breeding season and some will breed throughout the year.

Personnel of the International Sheep and Goat Institute have therefore been conducting research to determine how the breed variations in reproduction and production capabilities associated with different environments might be used to increase the level and efficiency of production throughout the world. Some of our results can be exemplified in terms of the Peliguey sheep in Mexico, the St. Croix sheep from the US Virgin Islands, various breeds in Iran, and Corriedales imported to Bolivia. Our studies with the Peliguey were conducted in the state of Tamaulipas in cooperation with Jorge de Alba and Arnoldo Gonzalez-Reyne of the Mexican Association of Animal Production. The Peliguey sheep has become so important to livestock production in Mexico, it has been designated an essential, non-exportable resource.

The Peliguey (a hair rather than a wool producing sheep) (Figure 6) varies in color from white to light brown or fawn color. The mature females weigh approximately 33 kg (72 pounds). Their average age at puberty is 245 days at an average weight of 23 kg. The average number of lambs born per mature ewe that lambs is 1.2.

One of the most unique characteristics of the Peliguey is its short interval between successive lambings. The average is 198 days (or approximately 6 1/2 months) with about 80 percent of the ewes lambing at intervals of 6-7 months. The Peligueys thus have a potential for lambing twice per year, where US breeds usually lamb once a year. Additionally, although this breed has a relatively low lambing rate of approximately 1.2, the proportion of embryos or fetuses lost during pregnancy is less than 10 percent (one-half or less than the rate of most US breeds).

The St. Croix (Figure 7) from the US Virgin Islands is also a hair sheep very similar in appearance to the Peliguey except that they are primarily white and are larger, with the mature female averaging approximately 55 kg (121 pounds) and the males 74 kg or 163 pounds. The average lamb weight at birth is 2.75 kg or 6 pounds compared to about 2.5 kg for the Peliguey.

St. Croix sheep are reported to lamb throughout the year in the Virgin Island of St. Croix. During their first year in Utah, however, they demonstrated a breeding season similar to that of US sheep, reflecting their response to the different environment. When St. Croix ewes were tested in Utah for the ability to lamb twice a year, approximately fifty percent of the ewes lambed consecutively at six-month intervals for at least three periods. They produced 2 to 2.5 lambs at each lambing.

Less than five percent of the straight-bred Rambouillet, which are a major US range sheep, lamb consecutively at six-month intervals. Data on lambs from a St. Croix/Rambouillet cross are not yet available.

In the US, considerable interest has been demonstrated in the St. Croix breed-type for commercial production. To help determine the economic practicality of such an effort, St. Croix sheep (under the direction of Utah State University's International Sheep and Goat Institute) are also being studied in Ohio, Florida, and California.

Twelve of Iran's eighteen breeds of native sheep were studied to see how their reproduction capabilities were influenced by season of the year (Figure 8). Our preliminary results (Table 5) indicated that time of year significantly affected breeding potentials of tested breeds.

In Bolivia, the effects of different seasons of the year on reproduction were measured in the Corriedale breed of sheep, some of which had been imported several generations earlier and had become adjusted to the Bolivian environment. The data (Table 6) indicate that Bolivia's proximity to the equator, with its stability in daylight hours during the year, encouraged equally stable reproductive potentials year round, except that fertility appeared to be reduced in the late (or winter) period.
FIGURE 6. The Peliguey (a hair rather than wool producing sheep) varies in color from white to light brown. The mature females weigh about 33 kg (72 pounds). Their average age at puberty is 245 days at an average weight of 23 kg. The average number of lambs born per ewe is 1.2.

FIGURE 7. The St. Croix from the US Virgin Islands is also a hair sheep very similar in appearance to the Peliguey except that they are primarily white and are larger, with the mature female averaging approximately 55 kg (121 pounds) and the males 74 kg or 163 pounds. The average lamb weight at birth is 2.75 kg or 6 pounds, compared to about 2.5 kg for the Peliguey.

FIGURE 8. Dr. Hessam Taleghani, Iranian cooperating scientist, performs surgery to measure ovulation rate in native Iranian sheep.

FIGURE 9. Llamas, highly valued as a meat and fiber source as well as pack animals, were studied at the Patacamaya Experiment Station. It was found that they do not have regular estrous cycles, but have constant estrus for 30 days and less frequently for as long as 90 days.
### TABLE 1. Average birth weights and gains of rate for some native Iranian breeds and their crosses with imported rams.1

<table>
<thead>
<tr>
<th>Breed</th>
<th>Dam</th>
<th>Birth Weight (kg)</th>
<th>Daily gain (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suffolk</td>
<td>Ghezel</td>
<td>5.794</td>
<td>.3234</td>
</tr>
<tr>
<td>Ghezel</td>
<td>Ghezel</td>
<td>4.335</td>
<td>2.666</td>
</tr>
<tr>
<td>Chios</td>
<td>Ghezel</td>
<td>4.696</td>
<td>2.436</td>
</tr>
<tr>
<td>Baluchi</td>
<td>Ghezel</td>
<td>4.997</td>
<td>2.227</td>
</tr>
<tr>
<td>Baluchi</td>
<td>Ghezel</td>
<td>4.638</td>
<td>2.148</td>
</tr>
<tr>
<td>Baluchi</td>
<td>Ghezel</td>
<td>4.349</td>
<td>1.949</td>
</tr>
<tr>
<td>Baluchi</td>
<td>Ghezel</td>
<td>4.0410</td>
<td>1.5410</td>
</tr>
</tbody>
</table>

2. P < .05 for means not having the same superscript letter.
3. Gains from birth to 60 days of age (weaning).

### TABLE 2. Average lamb weights and gains to five months of age (kg) from native and crossbred ewes in Iran.1

<table>
<thead>
<tr>
<th>Breed</th>
<th>Average weight at five months</th>
<th>ADG1 (5 mo.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rams</td>
<td>45.8</td>
<td>13</td>
</tr>
<tr>
<td>Chios x Ghezel</td>
<td>59.3</td>
<td>16</td>
</tr>
<tr>
<td>Suffolk x Ghezel</td>
<td>40.0</td>
<td>9</td>
</tr>
<tr>
<td>Suffolk x Chios x Baluchi</td>
<td>41.3</td>
<td>9</td>
</tr>
<tr>
<td>Suffolk x Kellakui</td>
<td>46.0</td>
<td>9</td>
</tr>
<tr>
<td>Awasil</td>
<td>33.8</td>
<td>9</td>
</tr>
<tr>
<td>Chios x Baluchi</td>
<td>33.3</td>
<td>9</td>
</tr>
<tr>
<td>Ghezel</td>
<td>39.9</td>
<td>9</td>
</tr>
<tr>
<td>Chios x Ghezel</td>
<td>36.0</td>
<td>9</td>
</tr>
<tr>
<td>Mogani</td>
<td>33.2</td>
<td>—</td>
</tr>
</tbody>
</table>

2. Average daily gain. Number of lambs varied from 15-40.

### TABLE 3. Birth weight and growth rate of native and crossbred lambs in Iran (kg).1,2

<table>
<thead>
<tr>
<th>Breed</th>
<th>Birth weight 90 days</th>
<th>180 days</th>
<th>270 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suffolk x</td>
<td>5.98 ± 2.2</td>
<td>25.5 ± 2.4</td>
<td>40.13 ± 3.1</td>
</tr>
<tr>
<td>Ghezel</td>
<td>28 ± 0.3</td>
<td>17 ± 0.1</td>
<td>11 ± 0.1</td>
</tr>
<tr>
<td>Suffolk x Ghezel</td>
<td>4.68 ± 0.7</td>
<td>22.1 ± 0.8</td>
<td>33.9 ± 0.9</td>
</tr>
<tr>
<td>Ghezel</td>
<td>25 ± 0.1</td>
<td>13 ± 0.1</td>
<td>12 ± 0.1</td>
</tr>
<tr>
<td>Chios x Ghezel</td>
<td>5.1 ± 0.1</td>
<td>19.1 ± 0.8</td>
<td>31.6 ± 0.9</td>
</tr>
<tr>
<td>Ghezel</td>
<td>21 ± 0.1</td>
<td>14 ± 0.1</td>
<td>11 ± 0.1</td>
</tr>
<tr>
<td>Chios x Awasil</td>
<td>4.77 ± 0.8</td>
<td>19.4 ± 0.6</td>
<td>29.5 ± 0.8</td>
</tr>
<tr>
<td>Baluchi</td>
<td>22 ± 0.1</td>
<td>11 ± 0.1</td>
<td>0.7 ± 0.1</td>
</tr>
<tr>
<td>Awasil</td>
<td>5.49 ± 2.3</td>
<td>15.7 ± 0.2</td>
<td>28.5 ± 1.2</td>
</tr>
<tr>
<td>Baluchi</td>
<td>17 ± 0.1</td>
<td>0.14 ± 0.1</td>
<td>0.08 ± 0.1</td>
</tr>
</tbody>
</table>

2. All weights are adjusted to the basis of a single born male. Number of lambs varied from 10-40.

### TABLE 4. Reproductive performance of Finn x Awassi F₁ and F₂ ewes in comparison with Awassi (A) ewe in Israel.8

<table>
<thead>
<tr>
<th>Breed</th>
<th>A</th>
<th>F₁</th>
<th>F₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lambed</td>
<td>%</td>
<td>30</td>
<td>84</td>
</tr>
<tr>
<td>Dry</td>
<td>%</td>
<td>70</td>
<td>16</td>
</tr>
<tr>
<td>Lambs born/ewe exposed</td>
<td>%</td>
<td>31</td>
<td>101</td>
</tr>
<tr>
<td>Lambs born/ewe lambing</td>
<td>%</td>
<td>104</td>
<td>121</td>
</tr>
<tr>
<td>Multiple births/ewe lambing</td>
<td>%</td>
<td>3</td>
<td>71</td>
</tr>
<tr>
<td>Lambing age:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>d</td>
<td>457</td>
<td>404</td>
</tr>
<tr>
<td>S.D.</td>
<td>d</td>
<td>29</td>
<td>64.4</td>
</tr>
<tr>
<td>no.</td>
<td>29</td>
<td>67</td>
<td>18</td>
</tr>
<tr>
<td>Weight of dam8</td>
<td>kg</td>
<td>49</td>
<td>53</td>
</tr>
<tr>
<td>S.D.</td>
<td>kg</td>
<td>6</td>
<td>11</td>
</tr>
<tr>
<td>no.</td>
<td>9</td>
<td>39</td>
<td>7</td>
</tr>
</tbody>
</table>

9. Three days post-partum.

### TABLE 5. Ovulation rates during each quarter of the year for seven breeds of native Iranian sheep (Ovulation rate/ewe ovulating).1

<table>
<thead>
<tr>
<th>Year</th>
<th>Breed1</th>
<th>October-December</th>
<th>January-March</th>
<th>April-May</th>
<th>June-September</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>1973-74</td>
<td>Awasi</td>
<td>1.37</td>
<td>1.21</td>
<td>1.00</td>
<td>1.17</td>
<td>1.24</td>
</tr>
<tr>
<td></td>
<td>Baluchi</td>
<td>1.11</td>
<td>1.00</td>
<td>1.00</td>
<td>1.24</td>
<td>1.09</td>
</tr>
<tr>
<td></td>
<td>Kallakui</td>
<td>1.11</td>
<td>1.00</td>
<td>1.11</td>
<td>1.00</td>
<td>1.06</td>
</tr>
<tr>
<td></td>
<td>Ghezel</td>
<td>1.39</td>
<td>1.22</td>
<td>1.00</td>
<td>1.00</td>
<td>1.21</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>1.24</td>
<td>1.11</td>
<td>1.02</td>
<td>1.19</td>
<td>1.14</td>
</tr>
<tr>
<td>1974-75</td>
<td>Shahil</td>
<td>1.15</td>
<td>1.09</td>
<td>1.00</td>
<td>1.18</td>
<td>1.11</td>
</tr>
<tr>
<td></td>
<td>Ghezel</td>
<td>1.23</td>
<td>1.22</td>
<td>1.00</td>
<td>1.00</td>
<td>1.12</td>
</tr>
<tr>
<td></td>
<td>Karakul</td>
<td>1.27</td>
<td>1.00</td>
<td>1.00</td>
<td>1.23</td>
<td>1.15</td>
</tr>
<tr>
<td></td>
<td>Mehreban</td>
<td>1.23</td>
<td>1.00</td>
<td>1.11</td>
<td>1.22</td>
<td>1.14</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>1.22</td>
<td>1.08</td>
<td>1.03</td>
<td>1.16</td>
<td>1.12</td>
</tr>
<tr>
<td>Combined Average</td>
<td>1.23</td>
<td>1.09</td>
<td>1.03</td>
<td>1.13</td>
<td>1.12</td>
<td></td>
</tr>
</tbody>
</table>

2. Approximately 20 ewes per group.

### TABLE 6. The influence of time of year of breeding on reproduction in imported Corriedale sheep in Bolivia.

<table>
<thead>
<tr>
<th>No. ewes</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>March 1- April 4</td>
<td>18</td>
<td>22</td>
<td>15</td>
<td>13</td>
</tr>
<tr>
<td>April 5- May 9</td>
<td>100</td>
<td>100</td>
<td>93</td>
<td>85</td>
</tr>
<tr>
<td>May 10- June 13</td>
<td>89</td>
<td>96</td>
<td>93</td>
<td>38</td>
</tr>
<tr>
<td>June 14- July 18</td>
<td>89</td>
<td>86</td>
<td>87</td>
<td>31</td>
</tr>
</tbody>
</table>

Cardozo and Choque, 1968.
Other South American Research

Since llamas make up a major proportion of the livestock on the high plateau or Altiplano of Bolivia, as well as in areas of neighboring countries such as Peru and Chile, their low levels of reproduction and therefore production are of concern (Figure 9). Llamas are valued as producers of meat and fiber, and as pack animals. As part of USU’s contract with USAID to help Bolivians increase their agricultural production, we began an investigation of this new world camel in 1966 at the Patacamaya Experiment Station on the Bolivian Altiplano. We found that female llamas do not have regular estrous cycles as do farm animals such as sheep, cattle, pigs, horses, and goats. Rather, they are in more or less constant estrus for as long as thirty days and less frequently for as long as ninety days. This is followed by a period of unpredictable duration when they will not mate. They then enter another extended period of estrus (England et al. 1971). Ovulation (egg production) processes of llamas are also peculiar, being more similar to those of rabbits, mink, ferrets, and cats, than to farm animals (England et al. 1969).

Additional data on mating behavior and responses to precipitation and/or temperature further confirmed that the llamas’ low rates of reproduction represent a physiological peculiarity of the llama and its relatives. Research with the new world camels now underway in Peru will add to the data accumulated earlier in Bolivia. We eventually expect to develop management procedures that will increase the capacities of these unique animals to provide food and fiber for human uses.

Basic Research

Practical efforts to extend livestock production in developing countries achieve their desired effects more quickly if they can be backed up by an extension of our understanding of the physiological and genetic mechanisms involved. As part of our international research, we therefore looked into how two native breeds of Iranian sheep (Baluchi and Kellakui) respond to hormone treatments designed to induce out-of-season breeding, and their subsequent fertility rates. A total of 58 ewes were treated with progesterone and an ovulation stimulating hormone, Pregnant Mare Serum Gonadotropin (PMSG). One hundred percent of the Baluchi and 94 percent of Kellakui ewes that were treated showed estrus and 75 and 94 percent became pregnant, respectively, with an average number of fetuses of 1.72 and 1.47. This can be compared to 44 percent and 0 percent incidence of estrus in the Baluchi and Kellakui ewes that received no hormone treatment, respectively. None of the non-treated Baluchi ewes that showed estrus became pregnant. These responses resembled those measured in other breeds.

Cytogenetic and blood chemistry analyses were conducted on twelve breeds of Iranian domestic sheep and various genotypes of wild sheep in an effort to determine genetic relationships. This research was done by Thomas Bunch, Juan Spillett, and James Bennett. All the domestic sheep had a chromosome number of 54, which had a karyotype of three pairs of metacentric chromosomes, 23 pairs of acrocentric autosomes, and one pair of sex chromosomes. The Armenian wild sheep from northwestern Iran had 54 chromosomes and a karyotype similar to that of Iranian domestic sheep. The urial, which is commonly found in the mountainous areas of eastern Iran, had 58 chromosomes. In hybrid zones, where these two types of sheep interbreed, their chromosome numbers range from 54 to 58. The identification of these hybrid populations of wild sheep in Iran have provided a basis for studies on reproduction and chromosome evolution in sheep.

Studies of blood hemoglobin and transferrin (a polymorphic iron-binding protein of the blood) have helped us identify relationships between wild and domestic breeds of sheep that may substantially facilitate efforts to breed improved types of sheep.

While helping people in LDCs better their standard of living, the work by the International Sheep and Goat Institute personnel has brought equally valuable benefits to USU, Utah, and the US. Much of what we’ve learned in foreign countries about animal production principles can be used in the US. At the same time, international markets have been opened to US sheep. Also, university personnel working in foreign countries have gained much in knowledge and experience that they can bring back to their classrooms and their research.

REFERENCES


Summary Report, International Sheep and Goat Institute, Utah State University, 1976.

ABOUT THE AUTHOR

Warren C. Foote is Professor in the Animal, Dairy, and Veterinary Sciences Department.

S P R I N G 1 9 8 1   5 3
1. Two Bolivian children tend sheep on the Altiplano.

2. A crude well dug to water level offers a cool drink during the dry season in Kenya.

3. James Bennett, USU, poses with native children in the Upper Volta.

4. Women offer grain at the market place in Cochabamba, Bolivia.

5. A young Bolivian family stands proudly in their successful wheat field.

6. Plowing a new field in Upper Volta with oxen and a mull board plow.

DERRICK J. THOM

Beyond Technological Band Aids

NOT EVEN MASSIVE DOSES of western technology and money can abolish rural poverty throughout the world. Beyond such band aid transfers of technology and money, developing countries need help in modifying their sociocultural traditions that can impose crippling inertia. For example, one way to reduce overgrazing on a range is to reduce the herd size, a simple solution for anyone who values animal quality over numbers. But to a pastoralist whose status as well as livelihood depend upon livestock numbers, a cut in herd size is tantamount to our reducing our bank account because we have too much money in the bank. Thus a simple solution becomes a complex problem that can only be solved through a knowledge of and compassion for values, attitudes, and institutions of the society in question.

Demographic characteristics, cultural institutions, and value systems must be assessed in relation to behavior. Other dimensions of effective aid center around: who has traditionally controlled which resources, where leadership is located, and how family and societal decisions are habitually made.
By looking at attitudes and social organization patterns of the people in less developed countries, humanists and social scientists identify what is acceptable or practical within their sociocultural context. The resultant systematic approach to understanding the causes of sociocultural constraints is proving invaluable in finding suitable and lasting remedies.

Through USU's Office of International Programs and the university's involvement in the Consortium for International Development, faculty from the College of Humanities, Arts, and Social Sciences have been serving overseas on both long-term and short-term assignments. From Timbuktu and Ouagadougou to Kuala Lumpur, Silang, and numerous other exotic but poverty-ridden places, their skills have been brought to bear on the problems of hunger, food production, and rural poverty. Our contributions have been in five main areas: (1) Language Training, (2) Project Design and Evaluation, (3) Human Resource Inventories, (4) Extension and Institution Building, and (5) Education.

**Language Training**

Many Americans involved in overseas development work have found that a lack of linguistic skills has severely hindered their efforts. Spanish or Portuguese is mandatory for work in Latin America and French is necessary over much of Africa. Members of USU's Department of Languages and Philosophy met this challenge by using a Title XII grant to initiate intensive conversational French and Spanish courses for technicians and their families preparing for overseas assignments.

**Project Design and Evaluation**

William F. Lye, Dean of USU's College of Humanities, Arts, and Social Sciences, provides one example of how sociologists, anthropologists, political scientists, historians, and geographers have assisted in designing projects to increase agricultural production in less developed countries. A specialist in African history, Lye has served as a Social Science consultant on interdisciplinary teams in the Sudan and Lesotho. In the Sudan, his knowledge and background in African ethnography helped earn AID and World Bank funding for a range management and subsistence farming project. In Lesotho, he provided the social and ethnographic insights needed for an integrated project in land reclamation and range improvement.

Wesley Maughan, a USU sociologist and extension specialist, led an AID educational design team that went to Upper Volta, West Africa in 1975. Working out of Ouagadougou, the design team developed strategies whereby the food and nutrition of people in selected areas could be improved through an extension educational program.

In 1977, Maughan returned to West Africa on another short-term assignment, this time to Bamako in Mali, as a Livestock Development Institution Specialist. By examining the organizational structure of the services and institutions in Mali that are involved in livestock production and improvement, he was able to make recommendations that will ultimately increase meat production in Mali.

William L. Furlong, one of USU's political scientists, worked with the Utah-Bolivia partners in 1978 to design and write a proposal for AID to create a rural development center on the Altiplano of Bolivia. Two aspects of the proposal dealt with food and hunger. The first was designed to teach women nutrition, food preparation, and improved food utilization. The second dealt with agricultural improvements and improved extension type services. Although AID and Congress approved money for the project, a stutter in US-Bolivian political relations has delayed implementation.

Short-term assignments to evaluate ongoing AID projects have been undertaken by Yun Kim, a sociologist, and myself, a geographer. In 1975, Kim provided the social analysis part of an evaluation of the Maasai Livestock Development Project in Tanzania. While there, he met Jon Moris, an anthropologist and team leader of the project. Moris subsequently joined the staff of USU to complement his work in Tanzania. I assisted in evaluating range and livestock projects in Botswana (1976) and Mali (1978) while providing the social impact statement and recommendations for improvement and redirection of the projects. In Mali the investigation of the range resources for the livestock sector report took me to the fabled Timbuktu, on the southern fringes of the Sahara. It was sobering to see how this city's past glories as a center for trans-Saharan trade and Islamic learning had faded with the area's dramatic decline as an entrepot center over the past 300 years.

**Human and Physical Resource Inventories**

Without adequate information on the human and physical resources within a developing country, many projects collapse before they achieve lasting results. Recognizing this, the Philippine government asked USU's Yun Kim to become involved in establishing the Population Research Division of the National Census and Statistics Office, National Economic Development Authority. From its start in 1970, the primary objective of this project was to maximize the utilization of population data collected from censuses and surveys for decision making and national and regional planning. As a result of the research, computer tapes containing the records of Philippine censuses and surveys have been made available to USU's Population Research Laboratory for faculty and graduate research. Utah State University is the only institution outside the Philippines with access to the data sets, one example of the two-way flow of international research.

In 1977-78, at the request of the government of Kenya and with funding
through AID, the Kenya Marginal/Semi­Arid Lands Pre-Investment Study project was undertaken. The objective was to assist Kenya’s Ministry of Agriculture increase food production through identifying the developmental resources of designated areas of semi-arid lands.

As social scientist in the eight-man interdisciplinary team, I was to determine the human and social characteristics of the designated areas.

A series of maps were eventually derived based on air photo interpretations and remote sensing techniques. The maps showed us population distribution and density factors, eco-climatic zones, soil capabilities, land-use, land adjudication, human carrying capacity, and percent of land cultivated. In addition to producing the maps, almost 3,000 farmers were interviewed to obtain a profile of the socioeconomic conditions of the smallholders in the marginal/semi-arid areas being studied. The questionnaire we used gave us information about household members by age and sex, their crops and livestock, and economic data on the farmers’ income and expenditure situations, housing, land tenure, and water supplies. We also tried to identify attitudes and perceptions of each farmer with respect to drought, food supply, and soil erosion. These baseline data on the condition of the people in the area were subsequently used in project identification and development planning, and were then preserved on computer tape stored at Utah State University.

Charles Killpack of USU’s Department of Landscape Architecture and Environmental Planning has been involved in human and physical resource inventory research in Malaysia. Through a grant from the World Bank/UNDP, he helped determine planning requirements with particular emphasis on computer planning methodologies and techniques. The Malaysian government especially wanted a map of the country’s resources that could be used for economic and natural resource planning, and to have the mapped data
Her man rides his burro as the woman leads the way, baby on her back and a basket on her head.

The water hole during the dry season is a popular gathering place for all.

A school constructed by the people of Chahuira Pampa, Bolivia, brought them together.

computer compatible with their existing socioeconomic data. By achieving these goals, the government has been able to make fact-based choices between alternative ways to manage resources so as to lessen poverty and malnutrition.

Extension and Institution Building

Beginning with the work of Welling Roskelley in the 1950s, USU sociologists have participated in extension and institution building projects in developing lands. In 1968, through an AID-sponsored Rural Development Project, Roskelley co-authored a handbook on Building Institutions to Serve Agriculture. His later work on the Farmer Scholar Program in the Philippines brought further honors and recognition.

Most recently, sociologists are participating in a four-year Tanzanian Project (1979-83) funded by USAID for $1.7 million. A direct outgrowth of previous work by Jon Moris in Tanzania, this project builds upon his participation in the Faculty of Agriculture at the University of Dar es Salaam. He assisted in the establishment of a Department of Agricultural Education and Extension at the agricultural campus located at Morogoro, Tanzania by hiring faculty, developing a curriculum, and acquiring funding from the government of Tanzania for the construction of a Center for Continuing Education. He was also instrumental in establishing a faculty-wide Audio-Visual Service Unit that can disseminate information to the farmers. The new department is expected to establish linkages between research, training, and extension components and is modelled on the US land-grant type relationship.

Under the direction of Moris the Faculty of Agriculture in the Center for Continuing Education will be increased, and emphasis on small-farmer needs will be strengthened within degree-level training. The new four-year project also calls for the provision of vehicles, audio-visual equipment, and the development of teaching methods and curriculum.
materials specifically geared to meeting farmers' needs.

The USU team leader is David Giltrow, an Audio-Visual specialist who will be accompanied by J. Lewton Brain, an Agricultural Education and Rural Sociologist specialist, and Courtney Brewer, an Extension specialist. Other USU staff members will be involved on short-term bases.

This four-year project is expected to change the Tanzanian government's own institutional capacity to serve agriculture and thereby lead to more food production in the country. Tanzania has had to rely on outside food imports on several occasions in recent years because of drought or flooding within the country. The country is ecologically diverse enough, however, to support itself once its organizational constraints are solved. Changing the capacity of Tanzania's own major training institution to prepare agriculturally oriented professional and technical staff is one crucial step toward self-sufficiency in food production. The other is the concomitant perfection of ways to get information to the farmers.

**Education**

Most international projects include an education and training component whereby our staff members are assigned host country counterparts who work together with them in an on-site training capacity. Some projects also provide funding for advanced training for qualified host country personnel. For example, ten Tanzanians from the University of Dar es Salaam and related technical ministries will complete their higher level training in the United States prior to their replacing the USU personnel in Tanzania. Most of the ten are in agriculturally related fields. Two are currently enrolled in PhD level programs at USU.

Over the past ten years, more than two dozen students from developing countries have graduated from USU with Masters and PhD degrees in Sociology. Most of these graduates have returned to their native countries to fill responsible positions in their governments and universities. Yun Kim's involvement in the Philippines Project has resulted in a total of eleven Philippine scholars (sponsored by the United Nations and USAID) coming to USU for graduate studies in demography and sociology. Two have completed masters and doctorate degrees in demography and five have earned masters degrees in sociology. One is continuing her PhD work in economics at USU. Two others are completing a masters degree program.

At present, fifteen students working on advanced degrees in sociology are from developing countries (Thailand, Iraq, Korea, Iran, China, Greece, Japan, Libya, and the Philippines). Most of these students are funded by scholarships or fellowships from their governments, universities, international organizations, or private foundations. Their graduate studies are in demography, rural sociology and community, environmental sociology, and social psychology, and many are undertaking social and demographic research in developing areas, particularly Thailand, Korea, Iraq, and the Philippines.

USU's Department of Political Science offers a graduate program with an emphasis in public administration that has had a special appeal to foreign students. Since 1971 it has attracted more than 75 students from Thailand. Dozens of students from Korea, Japan, Nigeria, Iran, and Saudi Arabia have also graduated from the Political Science Department, most of whom returned to their homelands to occupy important positions in their governments.

Recently members of the Department of Political Science joined forces with personnel from the Departments of Economics, Business, and Sociology to develop a Master of Social Science program at the Instituto Regional Tecnologico de Tijuana in Tijuana, Mexico. Through special contractual arrangements with the government of Mexico, faculty from USU will teach courses in Tijuana in Spanish, with the coursework to be completed on the USU campus. This program will meet the needs of professionals who want to develop expertise in Public Administration and provide a cadre of teachers for teaching Public Administration in the universities of Mexico. If the program is successful, comparable efforts could be initiated in Arabic-speaking countries through Amal Kawar of USU's Department of Political Science.

Political scientists are also involved, with personnel from other social science departments and the College of Agriculture, in teaching Public Administration-related courses in the International Agricultural Extension Program, a program designed for foreign students. Foreign students interested in agriculture can thus learn about administration techniques.

The College of Humanities, Arts, and Social Sciences offers an interdisciplinary certificate in International Development through the Area Studies Program. The International Development Certificate program is funded by Title XII to assist technicians in gaining a better sociocultural perspective of the problems in less developed countries and to assist social scientists to appreciate the technical problems of development. Students who anticipate careers in overseas development work can use the program to make themselves more competitive in the job market.

In this, as in most of our internationally relevant work, we are on a two-way street. What we do to help individuals and countries comes back in many forms. The countries become more self-sufficient in agricultural production, thus lessering their need for costly aid programs. And as individuals come here to study, they broaden the horizons of USU and the community.

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**ABOUT THE AUTHOR**

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THE AUTHORS OF THE ARTICLES in this issue of UTAH SCIENCE have eloquently described some of our past efforts to help less fortunate peoples help themselves. Our commitment to such work is ongoing for both selfish and altruistic reasons.

By establishing a person-to-person relationship with individuals in less developed countries, station scientists have achieved beneficial results that outlast transitory political gyrations. Farmers who see their production increase and scientists who learn effective field/laboratory techniques rarely regress. That makes for the kind of sustained attack on world hunger we must encourage if the world we know is to survive.

At the same time, much of what our scientists do in other countries translates into immediately tangible benefits to Utah and the nation. As described in this magazine, we reap dollars, know-how, and plant and animal genetic resources. Perhaps the most amazing aspect of this benefit side of the ledger is that it rests on a zero input of Utah dollars.

Our involvement in hunger-abating work outside of the US is funded entirely by external sources. Station personnel, while abroad, are supported by contracts with various government or private organizations. And yet, beneficial returns accrue to the state and the university.

I am gratified to present these representative accounts of what station personnel are accomplishing beyond our normal constraints. We will continue to join our efforts with those of other universities and agricultural experiment stations to help the poverty-stricken and hungry of the world find ways to improve their lives. From that commitment we expect to also continue to realize both short-term and long-term benefits.

DOYLE J. MATTHEWS
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