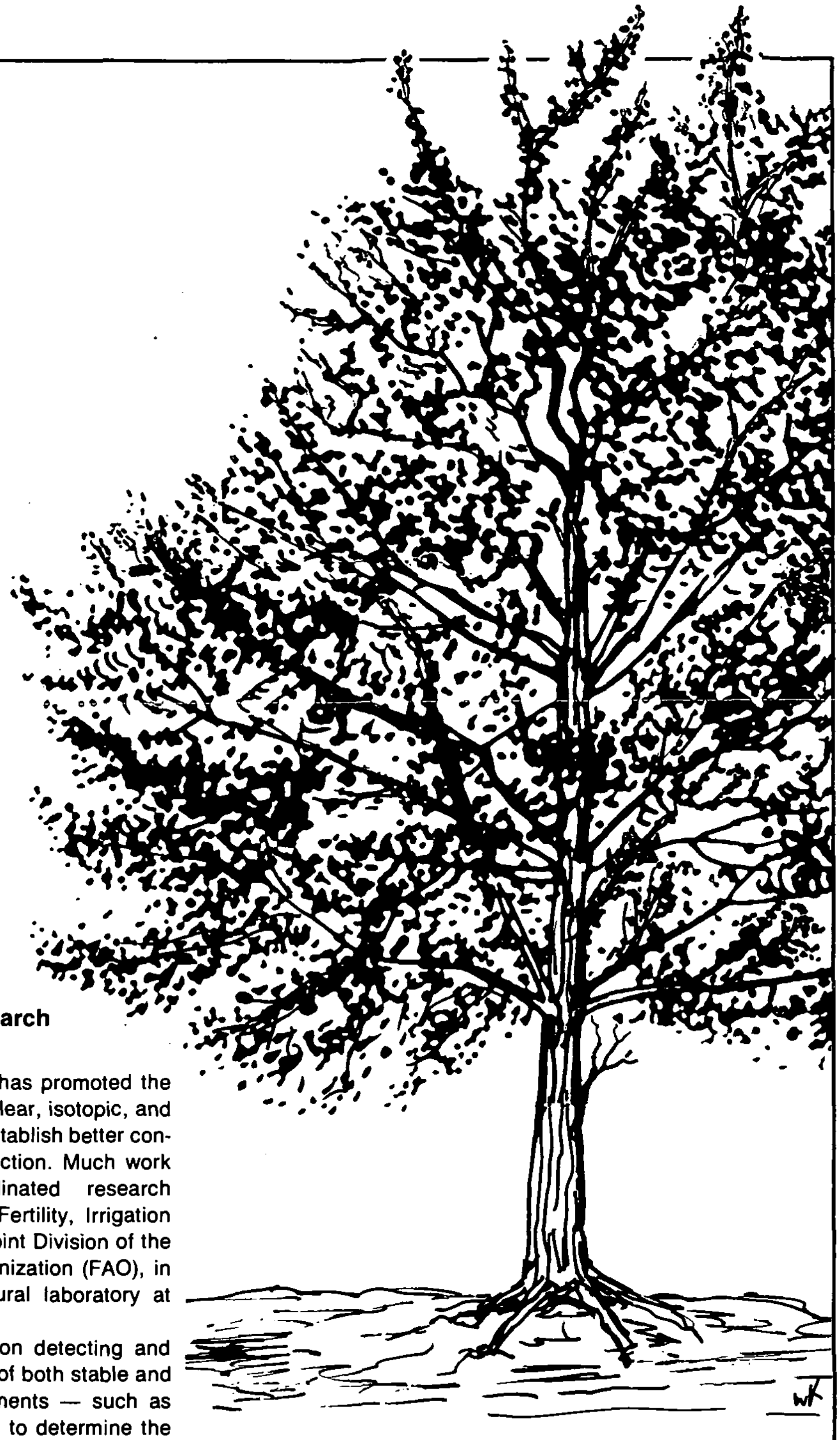

The IAEA in soil research

Over the past decades, the IAEA has promoted the study and development of various nuclear, isotopic, and related techniques to help countries establish better conditions for crop cultivation and production. Much work has been done through co-ordinated research programmes conducted by the Soil Fertility, Irrigation and Crop Production Section of the Joint Division of the IAEA and Food and Agriculture Organization (FAO), in collaboration with the IAEA agricultural laboratory at Seibersdorf, Austria.

Very sensitive techniques based on detecting and tracking the presence and movement of both stable and radioactive isotopes of common elements — such as nitrogen and phosphorus — are used to determine the amounts and movements of nutrients, especially those derived from fertilizers, in soils and plants. Several research programmes, for example, have concentrated on finding the most efficient way of applying nitrogen fertilizers to various crops, using the stable isotope nitrogen-15 as a tracer. The findings of these studies have been adopted in many countries around the world, resulting in savings of nitrogen fertilizers worth many millions of dollars every year. One important practical contribution has been the development of a research technique that enables measurement of the amount of nitrogen that plants actually fix under field conditions. This nitrogen-15 isotopic technique — now widely accepted around the world — helps agronomists to identify cropping practices, crop mixtures, and management methods that will yield maximum benefits under local agricultural conditions.

More technical information about activities and research on these and other topics in agronomy is available through IAEA publications. (See the *Keep abreast* section for ordering information.) These include:

- *Isotope and radiation techniques in soil physics and irrigation studies*, proceedings of a symposium held in France in April 1983 and jointly organized by the IAEA and FAO.
- *Nuclear techniques in improving pasture management*, proceedings of an advisory group meeting organized by the Joint FAO/IAEA Division and held in Vienna in 1980.

Nitrogen research for perennial crops

Scientists are studying the role of trees in restoring and maintaining soil fertility

by Glynn D. Bowen and Seth K.A. Danso

In many tropical countries, food production has increased at a lower rate than population growth. In sub-Saharan Africa, for example, population growth has outstripped food production in 35 out of 41 countries. The majority of tropical soils are either infertile, or fragile, and therefore need to be managed properly for increased food production. The dominant farming system in these areas is based on the shifting cultivation and bush fallow concepts, by which the land is cropped, usually for 3 to 5 years, and then left fallow, commonly for 4 to 10 years, to allow the soil fertility to regenerate. Perennial trees play a vital role in this process. Those that are able to fix atmospheric nitrogen have an added advantage in that they hasten this regeneration period by their rapid growth in soils poor in nitrogen, an essential nutrient element for plant growth.

Intensive cultivation in response to increasing population growth and food demands has led to shortening of rotation periods. This has resulted in drastically reduced soil fertility and increased erosion in the humid and semi-arid regions, thus bringing marginal lands under cultivation. Crop yields of most small-holder farms, therefore, have sometimes declined by as much as 70—80% within a year or two after clearing. In drier areas, overgrazing and harvesting of trees have been major factors in reduced productivity, soil erosion, and desertification (6 million hectares per year). The situation is likely to get worse, unless suitable remedies are found. The restoration of soil fertility through fertilizer application, as practiced in most developed countries, is often too costly to be adopted by most farmers in the tropics. Besides, 65% of tropical soils are fragile and therefore deteriorate rapidly under intensive cultivation.

In developing countries fuelwood also provides about 45% of the primary energy; this percentage could be double in rural areas. Deforestation has therefore caused another problem — increasing fuelwood shortages. The importance attached to fuelwood is great, and in some countries its collection consumes 40% of the daylight hours of women and children. In Africa, it is estimated that in some cities about one-half of the family's income is spent on charcoal, that 55 million people are now living in a fuelwood crisis, and that by the year 2000 this number could increase to 550 million (out of a projected population of 760 million). The World Bank has suggested that by the year 2000, three billion people will be living in areas where fuelwood is acutely scarce or has to be obtained from elsewhere.

Agroforestry and its benefits

Cropping systems that include trees can provide the ecological framework within which food, fuelwood, and fibre production can be integrated. By their perennial

Women collecting firewood in an African country.

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Deforested communal lands in the process of decline in Africa.

nature, extensive root systems, and frequently high biomass, trees have particular advantages over other systems: Annual planting is not required, and once established, trees play a year-round soil conservation role. They recycle nutrients inaccessible to most shallow-rooted food crops from deep soil layers to the surface horizon. They also provide organic matter and are used for stabilizing fragile soils. Nitrogen-fixing trees are particularly important because they can grow in soils deficient in nitrogen, and sometimes phosphorus. They can also contribute substantial amounts of nitrogen to the soil.

Legume-based pastures

Desertification — which is threatening almost one-fifth of the earth's land surface — primarily occurs in pasture and rangeland regions. Many scientists engaged in breeding for superior animals have gradually realized that, notwithstanding the importance of adequate management and health of tropical cattle, poor pasture production is by far the greatest constraint in marginal soil areas. With more grain being needed for direct human consumption, improvement in pasture productivity and nutritive quality becomes more critical. Acid infertile soils abound in the tropics. They account for about slightly more than half of the total land area in tropical America, equivalent to about 850 million hectares.* With proper plant selection and management, it has been shown that it is possible to grow luxuriant pastures on these soils, thereby releasing highly productive areas for food production. Forage legumes are particularly useful for these marginal soils because many of them are capable of converting some of the abundant nitrogen in the atmosphere for their growth. They can thus grow in soils deficient in nitrogen. In New Zealand alone, it is estimated that clovers in pastures fix in excess of 1 million tonnes of nitrogen annually, equivalent to more than US $1000 million of urea fertilizer.* Pasture legumes also have been shown to be capable of growing in phosphorus deficient soils, if they are infected by mycorrhizal fungi. Mixed legume-grass pastures, therefore, are capable of providing high biomass on infertile soils, and they are of high nutritive value. By their perennial and dense growth, they also protect soil from erosion and nutrient leaching losses, and they add substantial amounts of organic matter and nitrogen to boost soil fertility.

IAEA's work in the field

Realizing the importance of the problem, the IAEA has been actively involved in studies on nitrogen-fixing pasture legumes and is ready to embark on similar studies of trees. These programmes are under the Agency's Soil Fertility, Irrigation and Crop Production Section of the Joint Division of the IAEA and Food and Agriculture Organization (FAO). They are being done in co-operation with the IAEA's agricultural laboratory in Seibersdorf, Austria. Research encompasses work at Seibersdorf and 21 other laboratories in developing and industrialized Member States of the IAEA. Immediate objectives of the pasture programme are to develop suitable methodologies for measuring the nitrogen fixed in these perennials, to identify the management practices for maximizing nitrogen fixation, and to develop persis-

* See "Tropical pasture research in acid infertile soils of Latin America: Present status and needs for the future", by P.A. Sanchez in *Pasture production in acid soils of the tropics*, edited by P.A. Sanchez and L.E. Tergas, seminar proceedings, CIAT, Cali, Colombia (17-21 April 1978).

* See "The effect of invertebrates on nitrogen-2 fixation", report by K.W. Steel, R.N. Watson, and P.M. Bonish at the First Research Co-ordination Meeting, FAO/IAEA Co-ordinated Research Programme on the Use of Nuclear Techniques in Pasture Management, Vienna (14-18 November 1983).

Casuarina stricta, the dominant plant in a low nitrogen, low phosphorus soil in Australia with 200 millimeters annual rainfall.

tent and highly productive legume-grass pasture systems.

Nitrogen-15 isotope techniques, largely developed at Seibersdorf, have been successfully used for measuring nitrogen fixation in perennial pastures.* Results obtained so far indicate that several species are capable of satisfying more than 80% of their nitrogen requirements from atmospheric nitrogen fixation, making them highly desirable plants in nitrogen-poor soils. *(See accompanying table.)* The major efforts that are needed, therefore, appear to be management or breeding approaches that will increase biomass yield and, as a result, increase the amount of nitrogen fixed. The management aspects are being pursued now and include the effect of inorganic nitrogen, soil phosphorus levels, mycorrhizal infection, *Rhizobium* inoculation, and species compatibility in mixed pasture systems. It is hoped that the breeding aspect can be tackled later.

* For a report on the work at the Seibersdorf laboratory, see "Enhancing biological nitrogen fixation", by S.K.A. Danso and D.C. Eskew, *IAEA Bulletin*, Vol. 26, No. 2 (1984).

Nitrogen fixation by pasture legumes

	Year	Nitrogen fixed in per cent	
		Range	Average
Austria	1983–84	71–98	88
United States	1983	72–86	80
Greece	1984	52–93	81
Colombia	1985	48–89	68
Sudan	1984	77–90	84
Iceland	1985	94–97	96
New Zealand	1984–85	71–90	84
	Mean	48–98	83

The table shows the ranges and averages of nitrogen fixed by pasture legumes in various countries participating in the FAO/IAEA co-ordinated research programme on the use of nuclear techniques to improve pasture management.

For tree crops, the IAEA hosted an advisory group meeting from 24-28 November 1986 that was attended by staff of the Agency, FAO, Swedish International Development Authority (SIDA) and 11 invited scientists from 7 countries. The group identified the most important questions that need to be addressed to maximize the beneficial effects of trees in restoring and maintaining soil fertility, and the roles that isotopes, nuclear, and related techniques can play in studying the management

Casuarina equisetifolia, a nitrogen fixing tree being used to stabilize coastal sands in Senegal.

of trees in agricultural/pastoral systems. Many important topics on nitrogen nutrition of trees were discussed. These included: Which trees fix nitrogen? What is known about their specific bacterial requirements? How can nitrogen fixation be measured (an important factor to critical studies of this topic)? What environmental factors affect nitrogen fixation and return of litter to soil?

The meeting strongly recommended the integration of trees, especially nitrogen fixing trees, into stable agroforestry systems and semi-arid sylvo-pastoral systems. The potential of such trees is already evident in alley-farming systems in the humid tropics (where rows of trees are alternated with several rows of food crops). It was agreed that isotopic and nuclear techniques, many of which were developed at the IAEA, have a unique and important role to play in elucidating the best ways to manage trees in agroforestry systems and how to maximize nitrogen fixation and tree growth for restoring soil fertility and conserving soil resources.

Nuclear research for improved rice harvests

Many Asian rice farmers have known for centuries that the aquatic fern *Azolla* is a natural organic fertilizer for their flooded crops. Today scientists are looking at ways to spread *Azolla*'s use to more varieties of rice grown under different environmental and agricultural conditions as part of efforts to improve harvests. Rice is a staple food for two-thirds of the world's population.

Through a co-ordinated research programme now into its third year, the IAEA, Food and Agriculture Organization (FAO), and Swedish International Development Authority (SIDA) are jointly supporting research in this field. One focus is on systems of biological nitrogen fixation, specifically the symbiosis of *Azolla* with blue-green algae (cyanobacteria). Although the atmosphere contains an inexhaustible reservoir of nitrogen, the triple-bonded dinitrogen molecule is not available to plants and animals. Certain bacteria and cyanobacteria, however, produce the enzyme nitrogenase that reduces the dinitrogen molecule to ammonia, which can be used for protein synthesis. In the *Azolla* fern, the nitrogen-fixing cyanobacteria *Anabaena azollae* is found in the leaf cavity. When the fern is grown in rice paddies, it can accumulate within a month 30-60 kilograms of nitrogen per hectare of rice crop, and yield increases of up to 1.5 tonnes per hectare have been observed after its efficient incorporation into soil. Since chemical nitrogen fertilizer applications are commonly in the range of 60-100 kilograms of nitrogen per hectare for paddy rice, and *Azolla*'s nitrogen availability to rice has been found to be similar to that applied in the form of urea, *Azolla* clearly has a great potential.

Research is important, since genetically improved rice varieties of the "Green Revolution" require more nitrogen. So far, this extra nitrogen has been supplied by chemical nitrogen fertilizers. They have proved to be expensive, however, and outside the reach of poor farmers.

The IAEA/FAO/SIDA programme seeks to quantify the amount of nitrogen derived from nitrogen fixation, to evaluate the availability of the nitrogen to rice, and to develop *Azolla* management practices to increase rice yields. With techniques using nitrogen-15 as a tracer, evidence has been obtained that more than 80% of the nitrogen accumulated by *Azolla* is derived from nitrogen fixation and that the fern does not significantly compete with the rice for this nutrient.

Given *Azolla*'s potential, scientists are also studying ways to genetically improve the fern to broaden its applicability. The fern's spread into more rice growing areas has been limited in part by its sensitivity to several environmental stresses, including herbicides commonly used to kill weeds in rice paddies. In efforts to induce desired mutations and enhance *Azolla*'s genetic variability, scientists at the IAEA's Seibersdorf Laboratory have made initial attempts using ionizing radiation. They are also working to develop screening methods for traits of economic importance, as part of ongoing steps to foster *Azolla*'s utility as a biofertilizer for rice crops.