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**Impact of Agricultural Development on the Environment
- Issues in the Research Collaboration with Developing Countries -**

The orientation of German agricultural research

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The report "Our Common Future", published in 1987 by the World Commission on Environment and Development, the Brundtland-Commission, states: "The environmental difficulties that confront us are not new, but only recently have we begun to understand their complexity. Previously, our main concerns centred on the effects of development on the environment. Today, we need to be equally concerned about the ways in which environmental degradation can dampen or reverse economic development". In this report culminates a worldwide concern, which has grown over recent decades. A document submitted to the first FAO Conference in 1945 in Quebec already voiced this concern in relation to the soil, on which life on earth depends with the word: "Whether this thin layer of soil is to be a wasting asset or one maintained in perpetuity and made more fruitful for mankind will depend on how it is used and managed." One of our German senior agricultural scientists, Heinz Haushofer, wrote at the same time that the word of the bible "to subject the earth to men" has to be read today as "man is responsible for the earth and all its life".

The United Nations Conference on the Human Environment of 1972 in Stockholm amplified the worldwide concern on the state of the environment to numerous issues ranging from the pollution of land, water, and air to the destruction of the world's heritage of plant and animal genetic resources. The establishment of the United Nations Environment Programme following the Stockholm Conference, the U. N. Conference on Desertification of 1977, the World Conservation Strategy developed by the International Union for the Conservation of Nature in 1980, the World Soil Charter

adopted by the FAO-Conference in 1981, and the FAO Tropical Forestry Action Plan of 1985 are among the milestones expressing these concerns in international fora calling for actions on many fronts.

In 1974, the Consultative Group on International Agricultural Research with its major goal to increase food production in developing countries established the International Board on Plant Genetic Resources (IBPGR) to initiate counter-measures against the threat to plant genetic resources as the basis for future plant breeding. Following the recommendation of its Technical Advisory Committee the CGIAR included the aspect of sustainability of agricultural production in its goal statement and concluded in the report on Priorities and Future Strategies of 1987 that ecologically sound technologies and management practices for improved production are needed, tailored to the specific conditions of a wide range of agro-ecological zones and socio-economic situations.

The midterm meeting of the CGIAR in Berlin later this week will highlight the concern of the system with environmental issues in considering the Brundtland report and, in particular, the report of TAC: "Sustainable Agricultural Production: Implications for International Agricultural Research".

This preceding session of the CGIAR-Meeting, in which aspects of German agricultural research will be presented, will therefore be introduced by an overview focusing on research activities related to the impact of agricultural development on the environment. With the subsequent presentation by Dr. Leslie Swindale on respective developments in international agricultural research the session is also an introduction to the discussion of the Group's deliberation during the second half of the week.

The policy of the government of the Federal Republic of Germany

The growing international concern about environmental issues and the interdependence of development and environment, to which I referred in the beginning, is a reflection of national concerns, also in our country. Since the late 60's they have gained increasing attention in the public opinion and in the policy of the government of the Federal Republic. In a densely populated country, such as Germany, the effects of economic activities on the people, on individual aspects of the economy and on the natural resources have now become subjects of almost daily disputes.

Agriculture, having reached a high level of intensity in Germany as in other European countries, is no more considered only under the aspects of food production and as a custodian of the environment. It has also been critically observed for possible negative effects, such as water pollution, contamination of foods, and the reduction of the diversity of flora and fauna. At the same time, the destruction of forests through acid rains, the irreversible contamination of soils by heavy metals and the pollution of inland waters and the sea are phenomena which endanger agricultural forestry and fishery activities.

Hence, the goals of the agricultural policy in Germany give particular importance to environmental aspects, equal to its other priorities of the maintenance of economically viable farms and rural areas, of the production of high quality food and of world agriculture. Among numerous legal and regulatory measures in order to reduce negative environmental impacts of various economic activities the government has developed a special concept for soil protection in the Federal Republic of Germany. It serves as a framework to balance the conflicting interests of use of the soil and to prevent its destruction as well as long-term damage and risks.

Agricultural research in Germany has consequently become oriented towards environmental problems to a considerable degree, towards

those problems affecting agriculture, forestry and fisheries and those caused by agricultural activities. In 1987, environmentally oriented research has actually become the strongest growing sector within the federal research efforts in food and agriculture.

The government's policy in economic cooperation with developing countries also reflects this environmental concern. Its policy statement of 1986 lists as the two first priority areas for collaboration:

- food security through self reliance, in particular the increase of agricultural production and rural development and
- protection of the environment through increased support to relevant projects as well as through strict evaluation of all projects for their environmental consequences.

Therefore, within the government's development policy the orientation towards poverty, resource-poor farmers, ecologically and socio-economically adapted agricultural production methods enhancing productivity but preserving production resources receive particular priority. The prevailing concern about the impact of activities in development cooperation was recently highlighted in an international conference in Berlin. It concluded that much remains to be done to really reduce ecological destruction through development projects. The orientation towards ecological market economies was proposed. In the future, the costs for measures of environmental protection should already be included in development projects at the planning stage.

The agricultural research system in the F. R. of Germany

Before considering the main lines of German agricultural research in relation to the impact of agricultural development on the environment in the tropics and subtropics, it seems to be necessary to briefly describe our agricultural research system.

In this system both the public and the private sector play a considerable role.

Science and agriculture within the federal structure of Germany are under the authority of state governments; their universities and state institutions form one important component. 14 out of 55 scientific and technical universities in Germany have specialized faculties or departments in agriculture, nutrition, forestry and veterinary medicine. About 30 universities are connected with agricultural sciences through institutions concerned with biosciences and social sciences. In addition, there are 22 state institutes dealing with various aspects of applied agricultural research.

The Federal government, in its policy functions and its coordinating role, maintains its own research institutions and shares responsibility with the individual states in supporting of research and research institutions. The main concentration of agricultural research is under the Federal Minister of Food, Agriculture and Forestry (BML), which maintains 12 Federal Research Centres. Yet, research related to agriculture and environmental problems is also supported by other Federal Ministries, particularly the Minister of Research and Technology (BMFT). Prominent among the research organizations supported jointly by the Federal and state governments is the Max-Planck-Society, oriented towards basic research. Some of the Max-Planck-Institutes, particularly in plant genetics, are of prime importance for agricultural research.

Agricultural research in the private sector of Germany is prominent foremost in the fields of agrochemicals and biotechnology by the chemical industry. Plant breeding, too, is predominantly a private domain in Germany. Yet, its structure of middle-size firms allows only a few companies to sizeably invest in research. They, therefore, depend on a traditionally close collaboration with the respective public research institutes.

Within the agricultural research system, there is no central organization. Research planning is a too prone function. One major force comes from the level of individual scientists and research institutions. The other major force exists in the Federal and state governments developing research priorities and allocating research funds in demanding or promising research areas. Complex interactions at various levels exist between scientists, industry, agriculture and other private sectors with policy makers and administrators to set research priorities at government level. However, there are also mechanisms in research funding which are exclusively determined by scientific aspects. The German Research Foundation (DFG) is a major source to support research in basic as well as applied fields.

The Federal Minister for Economic Cooperation (BMZ) has no research institutes of its own. In agriculture, scientific and research matters of developing countries, he relies on the institutions and scientists in the existing German agricultural research system. The German Agency for Technical Cooperation (GTZ), which implements the largest share of agricultural development projects on behalf of the Federal Ministry for Economic Cooperation has a major demand for research support. This includes also the rehabilitation and the implementation of research infrastructure. Other organizations and foundations engaged in development cooperation in Germany also seek collaboration with agricultural research. Moreover, the genuine interests of agricultural scientists have developed a widespread, yet diversified, engagement of German agricultural and related research in developing countries.

Five universities, Berlin, Gießen, Göttingen, Hohenheim and Kassel, have specific centers for tropical and subtropical agriculture dealing with teaching and research in various relevant disciplines. However, their activities only represent a small part of the total research engagement dealing with agriculture, forestry and fisheries in developing countries. Individual research groups or specialized institutes, often

outside agricultural, forestry or veterinary faculties are of considerable importance.

In order to establish a focus in the Federal Republic of Germany for agricultural research for and with developing countries and, in particular, in support for the collaboration with the International Agricultural Research Centres of the CGIAR the Federal Ministers of Food, Agriculture and Forestry and for Economic Cooperation established the German Council for Tropical and Subtropical Agricultural Research (ATSAF) in 1976. ATSAF functions primarily as an advisor and as a forum for coordination. In 1986, ATSAF was instrumental together with GTZ and DSE (German Foundation for International Development) to publish a review of expert opinion of German agricultural scientists on priorities in international agricultural research. In regular seminars, the ATSAF surveys and updates ongoing agricultural research in Germany for the tropics and subtropics. It also provides the focal point for the SPAAR-information system on ongoing agricultural research support activities of German development cooperation and research institutions in Africa. The two publications provided for this meeting, the "Agricultural Research for the Tropics and Subtropics" and the "Highlights of German Agricultural Research Projects in the Tropics and Subtropics" by the BMZ and the BML, the I.C.T., and the Technical University of Berlin, have been prepared in collaboration with ATSAF.

The compilation of agricultural research projects in Germany illustrates the wide diversity of research interests for and with developing countries, covering a number of disciplines involved. Based upon this compilation some of the major lines of the research efforts relevant to the environmental impact of agricultural development will be exemplified.

Orientation of German agricultural research

The impact of agricultural development on the environment encompasses the aspect of sustainability of agricultural production as outlined in the TAC paper referred to before. The term environment includes the human population in and outside agriculture, forestry and fisheries as well as the biological and physical environment on which man depends for his survival, economic development and well being.

Major aspects in the orientation of German agricultural research are, therefore, to halt and reverse the ongoing degradation of natural resources, to restore and enhance their long-term productivity, at the same time meeting the increasing demands of the growing populations in developing countries and minimizing risks to human beings which may be caused by techniques of agricultural development. Within the German collaboration for agricultural development the productivity of agricultural systems in relation to natural resources from economic as well as sociological points of view is a primary goal. Optimizing and not maximizing production under given circumstances is the aim to be followed.

Assessment of resources

The assessment of soil, water and vegetation resources is a precondition for the development of sustainable land use systems and for monitoring the degree of and the causes for land and water degradation. There is a considerable involvement of research institutions of Geology, Geography, Photogrammetry, Forestry, Ecology and Soil Science in Germany to assist developing countries in such assessments or to develop suitable methods for land use planning. Such research includes:

- general mapping of the natural potential of the environment to avoid conflicts between various sectors in land use,

- inventories and continuous monitoring of forests under different forms of management and pressures,
- surveys to determine factors and dynamics of degradation processes leading to desertification and soil erosion and
- soil mapping for the suitability for irrigation.

The variety of methods used in land evaluation requires, as in the case of Mozambique, even research to establish compatibility between different methods to make use of earlier assessments in the land use planning of a particular country.

In research to determine the crop and livestock production potential, p. e. the agro-ecological zone approach of the FAO was further refined in Kenya down to the identification of farm enterprise zones in order to estimate opportunities for production systems to be used as a guide for agricultural planning.

Assessment research is not limited to natural resources. It also includes such aspects as the distribution and analysis of farming systems for rural development as in Sumatra, socio-economic systems as in the Sahel and Saharan zones of Africa or the inter-relationship of ecology and social structures as in Mali. Such research needs interdisciplinary approaches and often includes geography, ecology, sociology and agricultural socio-economics.

Agricultural policy and planning

Assessment research is in most cases closely related to regional and agricultural planning. In this field a number of institutions in Germany collaborate with developing countries on developing methodologies or on improving the required data base.

Research in agricultural policy is traditionally directed towards such aspects as planning, price and market policies and administrative structures. The aspect of environmental policies has become a more recent concern of research, p. e. in collaboration with Cameroon and China. Differences in environmental

concern and different possibilities to apply specific measures are determined by the different types of agrarian structures in prevailing various countries.

Soil resources

The environmental impact of agricultural development is of particular importance in the utilization, conservation and improvement of soil resources in developing countries. Therefore, soil research for the tropics and subtropics is increasingly shifting to aspects of careful utilization of this resource. Relevant basic research includes aspects of soil genesis, classification of weathering intensity, problems of soil structure, the role of organic matter in tropical soils, processes of salinization and of calcareous crust formations. Soil conservation and optimizing soil fertility and productivity however take a considerable share in the orientation of the 18 institutions in Germany being active in various aspects of soil research with developing countries.

Soil conservation and desertification

Research on soil conservation includes such aspects as the analysis of soil erosion processes and the development of regional soil loss formula in East Africa, the planning of soil protection measures, and the improvement of conservation practices under traditional and modern soil management and cropping systems.

Research has considerably contributed p. e. to the improvement of soil stabilization and productivity of farming systems in the state of Paraná, Brasil. Agricultural output per fertilizer input in this area decreased by 87 % over a 20 year period because of severe erosion. Through mulching, minimum cultivation and direct planting soil erosion could be averted. Direct planting increased economic returns at farm-level by 488 %.

Soil erosion is predominantly the result of malpractices of land use caused by the pressing needs of resource-poor people, by the overexploitation of land and very much by disregard or ignorance. Hence socio-economic research has to contribute in analysing its causes and in designing programmes for improvements and conservation.

This is particularly relevant in research to combat desertification. The Sahel project in Burkina Faso p. e. analysed the reasons of past failures to introduce desertification control programmes. The main reason identified was the insufficient involvement of the population concerned in all steps of actions to be implemented. These research results led to the development of a bottom-up approach in identifying problems with the peasants, joint planning, and implementation with clearly defined roles for different groups.

Soil fertility

The enhancement of soil fertility as a major factor to increase crop production receives high priority in our research efforts for developing countries. The main orientation is on optimizing plant nutrient supply in farming systems appropriate to soil properties and socio-economic conditions. Particular emphasis is laid on the situation of resource-poor farmers, where access to commercial inputs is difficult or impossible. Such research includes the improved recycling of nutrients from farm residues, green manuring, and biological nitrogen fixation. The optimizing of fertilizers is another part of this approach diminishing soil deficiencies, improving application measures and reducing losses and environmental contamination through percolation, sheet erosion and volatilization, particularly of nitrogen.

Research on the dynamics of soil nutrients and on the availability of individual nutrients for plant growth, particularly of phosphate to increase its solubility is included in the research agenda. Research groups in botany, plant physiology, microbiol-

ogy, and agronomy join in the efforts to exploit the V. A. Mycorrhiza for improved nutrient uptake in low fertility soils. Work on biological nitrogen fixation includes the Azolla-Anabaena symbioses in irrigated rice, the exploration of free living bacteria, such as *Aspirillum* in the rhizosphere of tropical grasses, and the improvement of nitrogen supply through the *Rhizobium* symbiosis of grain and forage legumes.

Water resources

Water availability is one of the most crucial factors for increasing crop production in tropical and subtropical countries. The most striking results to intensify agriculture have been under irrigation. Yet irrigation schemes are faced with numerous problems in water management and of waterlogging and salinity of soils having considerable environmental impact and endanger sustainability of production.

While hydrological research in Germany collaborates with developing countries in the assessment of water resources irrigation research is very much oriented to the improvement of existing irrigation systems and the reduction of negative environmental impacts. Research on the improvement of irrigation efficiency is supported by studies of water balance to reduce excessive water uses and methods to optimize water application for irrigation and leaching. Research to reduce salinization through improved water regimes and the lowering of the groundwater table is going on in Pakistan, India and Brazil. Traditional forms of irrigation systems are analysed in oasis situations and ancient irrigation schemes, such as the Marib dam in the Yemen, are studied to supply information on old techniques which could be useful for improvement today.

The use of waste water for irrigation near urban centers has also become an issue in developing countries. Research on pretreatments of domestic waste water and the monitoring of heavy metals

in irrigation water as a consequence of industrialization addresses such issues.

Socio-economic and organizational aspects of irrigation schemes are subjects of research because of their crucial importance for the functioning of irrigation systems in Arabian countries, in Malaysia and in Thailand.

Forest resources

Forest cover in the tropics and subtropics is disappearing in an alarming rate due to overexploitation by commercial interests, by land clearing for agriculture including shifting cultivation and most severely due to the energy need of rural and urban populations. German forestry research has a longstanding tradition in the tropics and subtropics, particularly in Asian and Latin American countries. Yet, there is also an increasing involvement in Africa.

Some priority areas of research are of particular relevance to environmental considerations. First is the analysis and understanding of forest ecosystems of natural forests and woodlands. They form the basis for designing systems of sustainable forest production which involve selective logging and natural revegetation. A cooperative programme of 15 German research institutions with China, projects on tropical forest ecosystems in Indonesia, in Liberia, in the Philippines and in the Araucarian forest of Southern Brazil are examples.

The development of methods of natural regeneration of already depleted forests is another priority area of research pursued in the Dipterocarpus-forest of Indonesia and the Pine forest of the central cordillera in the Philippines. Such areas need also ecologically adapted management practices to recover depleted forest ecosystems.

Thirdly, increasing attention in research is given to various forms of agroforestry as an important component of land use systems in order to stabilize soils, to recover depleted environments, to diversify agriculture and to overcome fuel energy shortages.

Genetic resources

German agricultural research has early joint in the now worldwide efforts to safeguard genetic resources in order to maintain biological diversity and, especially, to maintain plant and animal germplasm for future crop and livestock breeding. The Genebank for crop genetic resources of the Federal Republic of Germany was established in 1970 even before the IBPGR was founded. Although a national effort, it was international oriented from the beginning. The genebank collaborated in establishing similar institutions in important areas of plant genetic diversity in Ethiopia, Costa Rica and, more recently, in Kenya. Research in the exploration of genetic resources is pursued by a number of plant breeding institutes.

German research in plant breeding and crop improvement now reflects the serious concern about the impoverishment of genetic diversity nationally and in developing countries. The diversification of crops available to the farmers as alternatives in production is an important issue in Germany and Europe. In the collaboration of German research with developing countries traditional, yet scientifically neglected crops and the exploration of potentially new crops receive increasing attention. Tropical vegetables and fruit, minor root crops, medicinal plants, grain crops, such as Quinoa and Amaranthus, grain legumes, such as Lupinus mutabilis in the Andes, multipurpose trees and shrubs for agroforestry need to be mentioned.

In livestock research the better exploration and improvement of local breeds and neglected, traditionally used species reflect the orientation towards genetic diversity. Research on small

ruminants like goats and sheep and research on camels characterize this orientation. For the Vicuña, a camelide of the mountainous tundra of the high Andes able to utilize this marginal land, the principles were established of farming and managing this endogenous species. Research also started on neglected species like the grasscutter (or cane-rat), the preferred and most expensive meat in West-Africa and the Achat snails distributed over large parts of Sub-saharan Africa for which there is a great demand for human consumption.

Stress-tolerance and disease resistance

In respect to environmental degradation, the expansion of agriculture into marginal areas under the pressure of rapidly growing populations is a major concern. Only increased productivity of already cultivated land could alleviate this pressure. Yet, large areas of rainfed and irrigated agriculture in the tropics and subtropics are prone to various environmental stresses. Therefore, the selection and breeding of plant types tolerant to stresses, such as drought, heat, acid and saline soils are subject of various research programmes, including plant physiology, plant nutrition, genetics, and plant breeding. The possibility to breed crop varieties with improved nutrient uptake and efficiency receives broader attention in research programmes thus complementing the research efforts which deal with our national conditions, of reducing fertilizer inputs. Biotechnological methods, such as cell and embryo cultures promising in selection for stress tolerance and improved fertilizer use efficiency are included in the collaboration with developing countries.

Plant Protection

Among the problems of environmental impact of agricultural production, the chemical control of plant diseases, pests and weeds receive particular attention. The revolutionary impact

which the use of agrochemicals had on the intensification of agricultural production systems worldwide and the need to expand chemical pest control in developing countries to combat major pest outbreaks and to reduce pre- and postharvest losses are weighed today against the possible hazards and harmful effects of chemical pest control. Such effects include toxicity through incorrect uses, carryover by persistence in soils, pollution of water, contamination of food and feed, disturbances of ecosystems with serious threats to non-target organisms and the development of resistance in pathogens and pests. These problems may become aggravated in developing countries because of the lack of education, of trained personnel and services, of weaknesses in internal trade and in the possibilities to enforce regulatory measures as highlighted in the "International Code of Conduct for the Distribution and Use of Pesticides" of FAO. Moreover, large parts of resource poor farmers may not be able to effort the purchase of agrochemicals.

Plant protection has a strong research base in the Federal Republic of Germany in the private sector of the chemical industry but also in federal and university institutes. In addition institutes of the Max-Planck-Society and of biological, biochemical and ecological sciences at universities and in other public research bodies are important contributors to the understanding of basic principles such as host-pathogen relations. Throughout the private and the public research sector, problems of subtropical and tropical agriculture are important targets of the research agenda.

Integrated pest management strategies generally determine very much the orientation of plant protection research in order to reduce or even eliminate environmental risks yet being effective in ensuring against crop and yield losses.

The knowledge of the epidemiology of pathogens and of the population dynamics of pests forms the baselines on which integrated control strategies are developed. Hence a number of research programmes contribute to this knowledge including such

diseases as angular leaf spot of cotton, blast of upland rice, downey mildew of tropical maize, and black sigatoga of bananas. Research on population dynamics include gallmites in coconuts, stem borer in irrigated rice or the development of new methods for continuous recording of population densities of harmful insects and mites in various tropical biotopes.

The biological control of pests and weeds by predators and parasites and with the use of allelochemicals such as pheromones and kairomones is another important research area. Such work is pursued for a number of crop pests in African, Asian and Latin American countries. It includes among various target organisms the African migratory locust.

For plant protection chemicals research concentrates on less toxic and easy degradable substances. Furtheron new chemicals are of interest to control bacterial, virus and mycoplasm diseases of tropical crops for which no satisfactory control measures are available. Management systems for the application of pesticides are required in cases integrated control systems are not available to overcome the development of resistant pathogens, pests and weeds.

Natural pesticides from plants which can be grown also by small farmers and extracted by local means are subject of several research teams in Germany in collaboration with tropical countries. The neem tree of India adapted to a wide range of tropical conditions and other plant species are in the center of this research interest.

The resistance of crop plants is considered as a key factor in integrated control strategies. Research to develop detection methods of viruses and other difficult to diagnose diseases supports resistance breeding programmes e. g. in groundnuts, citrus, banana and others. Modern research methods such as DNA probes, protoplast fusion, somatic embryogenesis and tissue culture for haploid breeding support the work in resistance breeding.

Weed growth is a major limiting factor in the crop production of tropical agriculture. Many attempts to intensify traditional farming systems are hampered by increased weed problems which become aggravated by labour shortage in peak seasons. Research focuses on weed management systems in traditional cropping systems, on the development of new herbicides and on better approaches to control parasitic weeds such as Orobanche and Striga. On parasitic weeds an interdisciplinary group has started in Germany to bring together research experience of botany, chemical plant physiology, organic chemistry, microbiology, weed science and agronomy to better tackle the complex problems involved.

Livestock production and health

Within the priority areas which determine research for livestock production in Germany for the tropics and subtropics the aspect of animal genetic resources was already mentioned. Two further research areas, on natural grazing lands and on animal health, are of particular interests in considering environmental impact.

Grazing is the most extensive form of land use worldwide and of great economic importance in many tropical and subtropical countries. Yet, overgrazing and degradation of range lands are wide-spread phenomena with serious consequences on the environment and the sustainability of land use. The large scale conversion of tropical forests into grassland causes similar concerns.

German research is contributing to the analysis of causes of overexploitation and instability of grazing resources, to the reestablishment of natural grassland and of overgrazed arid lands. The improvement of grazing land through adapted forage legumes or through suitable forage shrubs is a special feature of such research. It includes p. e. the evaluation of Stylosanthes scabra as an important tropical forage legume. A crucial problem relates to the management of semi-arid and arid grazing land

where aspects of herd composition and herd management come strongly into the picture. Establishing parameters of animal nutrition is part of research in grazing and in animal feedstuff in order to balance livestock production with the availability of feed resources. It is also concerned with the causes and prevention of toxicity by many noxious plants widespread in natural tropical pastures of Latin America.

Research in animal health in Germany deals with various problems of tropical and subtropical livestock. Only a few should be mentioned. Animal trypanosomiasis, particularly the African one, is studied in the dynamics of transmission from the reservoirs of wild animals and in relation to changes in the ecology and the behaviour of the vectors. Basic research contributes to the molecular structure of surface antigens of trypanosome species. The causes, mechanisms and heredity of trypano-tolerance in various livestock breeds are research subjects of other laboratories and projects. New trypanocidal drugs are screened and one of our federal institutes serves as world reference center of FAO for the screening of acaricide resistance of ticks.

Furthermore German research has developed successful vaccination against rabies, a major threat to people and animals in many developing countries, and a new ELISA test kit for the detection of rinderpest using a non-infectious antigen.

Sustainable farming systems

The research areas exemplified so far contribute to the development of sustainable land use systems. I have concentrated the review on the orientation of research to alleviate negative effects of agricultural production and to avoid or redress degradation in order to illustrate research with a perspective of environmental impact. Hence important areas of agricultural research are excluded from this report p. e. those dealing with the production and quality of commodities, with market analysis, with farmers organisations and service institutions and many

other aspects important for sustainability as outlined in the paper of TAC.

The resource oriented research reviewed in the foregoing part of the paper is focussed on sustainable land use systems. In our research collaboration for development, sustainable resource use systems, in particular farming systems, are a major objective. This system approach therefore is reflected in various research efforts particular of socio-economic research.

The analysis of traditional farming systems, their social, cultural, ethnic, economical and ecological conditions and determinants are the subject of many research projects in countries of Africa, Asia and Latin America. This research includes such aspects as the ethno-specific knowledge of farmers of the natural environment, the interrelation of land use, land tenure and migration with soil erosion, the ecological consequences of the organization of herding in nomadic societies and the impact of change on the sustainability of systems. The main objective of this research is to establish elements and principles for the transition of traditional systems into those of higher productivity and of increased well-being of people which are ecologically, economically and from socio-cultural aspects sustainable. Changes in farm power and mechanization from hoe to bullock farming are further aspects of such research or the determination of elements for ecological land use in areas where rapid change through large scale mechanization has aggravated the loss of forest cover, fire wood shortage and soil erosion.

Of special interest is the development of smallholder farming systems which increase ecological stability, and economic viability, however minimize the dependence on commercial inputs. Ecological diversity in crops, integration of livestock, recycling of plant nutrients, the regime of organic soil matter and the control of soil erosion are elements of such ecofarming systems. Their acceptance by farmers however depends on many variables, not the least on their economic viability. More prominence in the development of sustainable systems for small

farmers have various forms of intercropping and particularly of agroforestry.

This review could illustrate only in a fragmented way the orientation of research in the Federal Republic of Germany towards the environmental impact of agricultural production. One weakness is that many of these research efforts are dispersed because of the structural nature of our research system. The fostering of interdisciplinary integration and cooperation is therefore an important task. The German Research Foundation (DFG) supports such integration in establishing Special Research Areas (Sonderforschungsbereiche). One of these is the programme of the University of Hohenheim on adapted forms of smallholder agriculture in the tropics with priority in West Africa.

The research on which I have reported represents a strong collaborative effort with scientists and institutions in many developing and developed countries, with the agencies, particularly the GTZ, responsible in the Federal Republic for the implementation of technical cooperation and last not least with the International Agricultural Research Centers of the CGIAR. The number of special projects and research contracts carried out with various IARCs, which German scientists would still like to see increased, did not allow individual references. Yet they are listed in the documentation provided to this meeting.

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