Proc 2nd ESA congress, Warwick Univ., 1992

'TEMPERATE' AND 'TROPICAL' AGRÓNOMY: A CASE FOR SYMBIOSIS

L O Fresco, Department of Tropical Crop Science, PO Box 341
6700 AH Wageningen, The Netherlands
P L G Vlek, Institute of Agronomy in the Tropics,
Grisebachstrasse 6, Göttingen W-3400, Germany

Abstract
Agriculture worldwide is confronted with many issues that cannot be solved on a regional basis only and call for global thinking and sharing of expertise. The supply of adequate quantities of food and agricultural products to unprecedented numbers of people requires a serious and long-term commitment to the design of sustainable agricultural systems as well as the ways to deal with global change. Fortunately, agronomic research and training dealing with 'temperate' and '(sub)tropical' environments share many of the underlying disciplines such as physiology and soil science. This provides the basis to deal with agricultural problems that are of a magnitude beyond the capacity of most scientists in the (sub)tropics. Rather than a one-sided application of the insights developed by 'temperate' agricultural science, a clear commitment of European scientists is required to make available relevant advanced methods and to allocate some of their capabilities in linking up with '(sub)tropical' research groups in Europe and elsewhere. The potential symbiosis between agricultural scientists worldwide must be recognised to allow '(sub)tropical' agronomists to mark their presence within ESA.

Introduction
There are three reasons to re-establish a closer linkage, or even a symbiosis, between '(sub)tropical' and 'temperate' agricultural science. Firstly, agriculture worldwide is confronted with global environmental issues that cannot be solved on a regional scale. Secondly, the need to provide adequate quantities of food to a rapidly expanding human population, most of whom live in the lower latitudes, requires a concerted effort from agricultural scientists, irrespective of their home base. Thirdly, the complexity of the (sub)tropical environments merits a greater scientific effort, because so many of its features are still poorly characterised. This paper addresses some of the issues in more detail and suggests some of the roles that European agronomists may play.

Latitude-specific issues
The tropics and subtropics cover 38 and 21% of the total land area of the earth, respectively (Dudal 1987). A great variety of climatic regimes, geology, relief, soils, vegetation and land use can be found within this (sub)tropical belt. While 60% of the tropics are humid to subhumid, the greatest extent of the subtropics are (semi)arid. Land use varies from extensive shifting cultivation and forest product harvesting to intensive permanent systems, which in turn may range from small-scale rice based farms to (irrigated) commercial cereal or cotton enterprises. The diversity notwithstanding, (sub)tropical environments and farming systems share a number of features that set them apart from the temperate world.

The historical roots of '(sub)tropical' agronomy are based in the 15-16th century discovery of overseas territories followed by their exploitation to satisfy markets of colonial powers, in particular in spices and stimulants, followed by fibers, hardwoods, and most recently, fruits and vegetables. Agronomy was dedicated almost exclusively to the production of these crops seeking the optimum ecologies in which the various crops could be produced and processed. Drastic innovations have led to major shifts in production centers and productivity, such as the introduction of rubber (<u>Hevea brasiliensis</u>) into SE Asia, or the discovery of the tenera hybrid of oil palm (<u>Elaeis guineensis</u>). During the colonial period, no systematic attention was paid to food crops, with the notable exception of several local programmes such as the work on rice by the French and the Dutch. From the 1960s onwards, decolonisation and concerns about rapid population growth led to the establishment of the international agricultural research centers, with IRRI and CIMMYT as pioneers, paving the way for the Green Revolution. Their strategy of intensification based on improved varieties of cereals, later followed by roots and tubers and grain legumes was largely succesful.

<u>Population growth</u>, however, leaves little reason for optimism. Rapid population increase is the key economic feature distinguishing the (sub)tropics from the rest of the world. Of the expected doubling of the human population to 10 or 11 billion people by the end of the next century, nearly the entire increase will take place outside the temperate regions. Today, one third of the population in developing countries lives in poverty, a more than proportional number of them being women. Already by 2025, 83% of world population will live in developing economies, most of which are situated in the (sub)tropics, a major exception being temperate China. The African population will have tripled, while Asia will witness the greatest absolute growth of all continents (from 2.6 to 4.4 billion in 2025). In many (sub)tropical countries the majority of the work force is still employed in the agricultural sector, but this may change rapidly. By 2025 nearly 60% of the population will live in cities, implying a staggering migration from rural areas (TAC 1991). Urban development will conflict more frequently with agricultural land use, and a relatively declining rural population will have to meet increasing urban demands.

<u>Productivity</u> The theoretical production maxima are higher in Asia, Latin America and Africa than in North America and Europe (Linnemann et al 1979). Average per hectare production, however, ranges far below these maxima and that of temperate countries (table 1).
Through an analysis of cereal production trends, De Wit et al (1979) have postulated a 'transformation point' situated at a yield level of 1700 kg, below which production growth is limited to 1-2% annually, and beyond which annual increases of 4-5% are attained. This point appears to correspond with a transition from production growth through area expansion to one based on technological intensification. For many crops (let alone cropping patterns) and in many regions this 'transformation point' has not been reached. A great challenge for tropical agronomy lies in understanding the processes and practises that allow farming systems to reach this critical stage. In all regions, except Africa, increases in per area productivity coincided with decreasing population growth rates (de Bruijn et

al 1989).

Crop	Temperate area yield (kg/ha)	Yield in tropics kg/ha	%[1]
Rice	4,109	1,958	48
Wheat	2,984	1,363	46
Maize	3,993	1,351	34
Sorghum	2,270	1,249	55
Soybean	1,620	1,038	64
Beans (dry)	1,079	640	59
Groundnut	1,667	1,036	62
Potato	18,056	8,704	48
Sweet potato	13,594	6,881	51
Cassava	11,844	9,103	77
Sugarcane	61,190	53,328	87

[1] Percent of temperate area yield (Source: Haws 1983)

Table 1. Average yields in the temperate areas and in the tropics.

The growth in agricultural production resulting from population growth has sofar largely been met by an extension of the area under cultivation, rather than through yield increases. The main exceptions to this are the rice, maize and potato growing regions of Asia and Latin America. This stands in sharp contrast to developments in the temperate world, where cultivated areas have declined and yields are rising steadily. There are indications that yield stability is systematically lower in tropics than in temperate regions (Anderson et al 1987). Generally speaking, tropical agriculture is characterized by a lower degree of control over the bio-physical environment, resulting in less management precision in the application of inputs and the timing of operations, and by a more limited range of socio-economic options. The most stable, high productive systems (in terms of relatively limited yield fluctuations and high dry matter yield per unit time and area) are irrigated rice (or wheat in cooler areas) and intensive home gardening. Many regions of the (sub)tropics, however, will have to depend on other farming systems for their livelihood.

Natural resources While in market economies only 36% of the total arable area is cultivated, this figure increases to 77% in developing countries. The shortage of arable land in developing countries is to a large extent the result of the fact that an estimated 2000 Mha have been severely degraded or lost through erosion (Lal & Stewart 1990). In China up to one third of the land has been more or less abandoned through erosion. Of the land between the tropics of Capricorn and Cancer (nearly 5 billion ha) 43% is found in Africa, 28% in South America and 20% in Asia. The vast majority of the developing countries fall within this region. A recent study by FAO (1989) concerning 93 developing countries, estimates that 57% of this land is of high quality with high potential for agricultural production due to good water supply (fig 1).

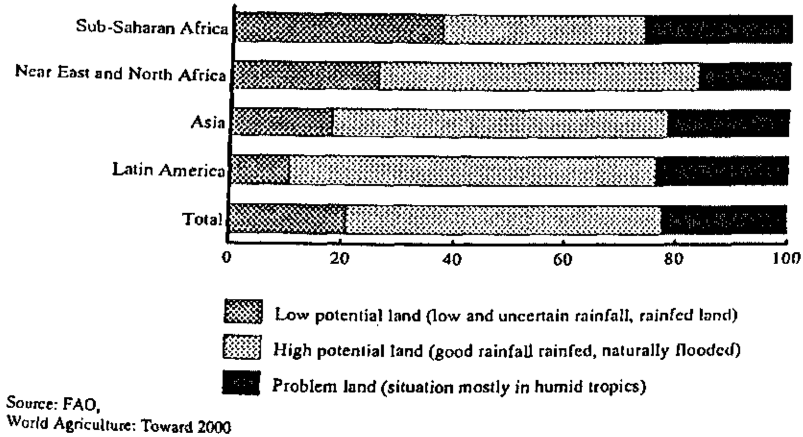

Fig 1. Shares of total harvested land of different potentials, 1982-1984 (93 developing countries)

The remaining land is considered to be of low potential due to low and uncertain rainfall (21%) or problem land with excessive rainfall and/or prone to erosion. High population densities have also led to the cultivation of lands in marginal environments, such as shallow mountain soils in the Himalaya or parts of the Andes, which were used formerly for extensive grazing or as tree reserves. Their clearing has led to large scale silting in downstream areas. In densely populated areas, such as the Philipines and Nigeria, erosion is rapidly becoming a major land use constraint.
Rainfall, or more precisely, water availability is not only inadequately documented in many cases, but, more importantly, is subject to large inter- and intra-annual variabilities that are poorly understood given the current data bases. This unpredictability fundamentally distinguishes the (sub)tropics from temperate environments.

Nutrient availability, which depends mainly on inherent soil fertility and nutrient application (and losses!) during cropping, is subject to large differences both within the (sub)tropics and between the (sub)tropics and temperate zones. Firstly, outside areas of relatively recent volcanic activity and young sedimentary plains, tropical soils are generally acid, of low inherent fertility and subject to considerable leaching in higher rainfall areas. The removal of natural vegetation for cropping and ranching has a detrimental effect on nutrient cycling, leading to losses of nutrients beyond the root zone (e.g. Jordan 1987), of which the long term implications are not yet adequately documented. Water erosion, leading to bulk losses of nutrient-rich topsoil and reducing actual rootable depth can be particularly severe in the (sub)tropics as a result of total high rainfall, high rainfall intensity of single showers, and erosion-proneness of certain tropical soils.

While soil organic matter levels of virgin tropical soils in the

(sub)humid environments do not seem to differ significantly from those in temperate regions, land clearing leads to rapid depletion of SOM because the high rates of decomposition are no longer matched by high rates of organic matter production (Sanchez 1976). The rapid rate of decomposition of organic matter in tropical soil was demonstrated by comparing the loss of ^{14}C labelled ryegrass in England and Nigeria (Jenkinson 1977). The results show a similar decomposition pattern irrespective of environment but 4-fold faster in the tropics. The loss of productivity following cultivation has been followed for over a century in various long-term experimental plots in the temperate zones. In the tropics such long-term trials are sorely lacking, causing scientists to rely on unreal time series to capture such changes over time. On the basis of an earlier sampled time series in Senegal with up to 90 years of continuous cultivation, leading to a decline in SOM in the topsoil from 2,85% under forest to 0,84% after 90 years, Pieri (1989) established that even after that time a true equilibrium had not been established.
Nutrient application through chemical fertilizers in the tropics, while increasing, is still largely insufficient to compensate for the losses due to crop removal. Fertilizer adoption has closely followed other technological innovations such as irrigation and modern varieties and is rarely used in non-improved cropping systems. Average application rates in Asia, Latin America and Africa stand at around 80, 40, and <10 kg nutrients per hectare, respectively. The use of manure, when viewed on a scale beyond the individual field merely implies translocation of nutrients and not an addition to the overall nutrient pool. While locally of importance, biological nitrogen fixation through legumes in the rotation or pasture is often limited by low phosphate levels and rarely compensates for nitrogen exports over multi-annual cropping cycles (Giller & Wilson 1991). According to a recent study commissioned by FAO annual nutrient depletion rates per hectare in sub-Saharan Africa alone amount to 10 kg N, 4 kg P_2O_5 and 10 kg K_2O per year (Stoorvogel & Smaling 1990).

Genetic diversity in the (sub)tropics far surpasses that anywhere else, as is aptly demonstrated by the high number of Leguminosae (296 out of 431 species) in the tropics as compared to the temperate regions. At the farm level, the introduction of modern varieties has had a major impact on the principal staples, rice, wheat and maize, which are increasingly based on a narrow parentage. There is growing concern over the disappearance of the broad based gene-pool from which these varieties originate and which may be needed to cope with future environmental and phytopathological stresses. Moreover, the degradation of habitats will endanger an increasing number of species which to date has led to an estimated loss of 100 species each day.
Farming systems in ecologically and socio-economically marginal environments are still characterized by the utilization of crop and animal species of great genetic diversity. This is true, a forteriori, for tropical grasslands where very few improved species have been introduced. The response of such material (landraces) both to conditions of stress and to improved management practices has not been systematically documented across agro-ecological zones, although genotype-environment interactions are being intensively studied in a few modern varieties. This situation differs sharply from that in temperate

regions where varieties are only released after thorough processes of screening and finetuning, and where the response of the material at the farm level is carefully monitored.

Yield reducing factors, i.e. losses due to pests and diseases are of great concern, especially in the humid tropics where the lack of a distinct dry season leads to a proliferation of pests and pathogens, and in areas where intensification has led to a limited rotation or even monocropping. According to some authors (e.g. Altieri 1987) traditional patterns of crop diversification prevailing in many parts of the (sub)tropics constitute a safeguard against widespread damage due to pathogens and predators. However, with the large scale movements of commodities world-wide in the form of food-aid, some exotic pests or pathogens may overrun agricultural systems that have little to offer in defense mechanisms and require high-tech assistance if catastrophies are to be avoided. The introduction of the cassava mealybug into Africa threatened to eliminate this important staple from the continent. Only the subsequent biological control program set up with extensive western aid helped to avoid a disaster (Neuenschwander & Hammond 1990). In other areas, e.g. Indonesia, farmer involvement in pest incidence monitoring and biological control has been effective in reducing outbreaks. Nevertheless, the degree of control, even in the most advanced tropical production systems, is well below the level common in temperate agriculture.
Weeds become increasingly important as traditional weed control through fallowing and burning is diminishing as a result of increasing population pressure, as transplanting is replaced by direct seeding, and as rural labour costs increase.

Global issues

There is an increasing awareness that the inherent fragility of the earth's resources and the sustainability of food and agricultural production are closely linked. In the next century, the world is likely to face a 2-3°C temperature increase (of which at least 1°C in the tropics), 10% increase in precipitation, 0.5 m eustatic sea level rise, a doubling of atmospheric CO_2 (Scharpenseel et al 1990). Although the overall contribution from agriculture to the greenhouse effect is dwarfed by that from fossil fuel consumption, the burning of major quantities of tropical biomass will continue to contribute significantly to the greenhouse effect. An estimated 75% of the greenhouse gases produced by such burning in the (sub)tropics is caused by the burning of savannas rather than of forests (Goldhammer 1990). Methane emisions from rice fields compound this problem. If realized, the effects of these changes are still uncertain, and are likely to affect the higher latitudes more dramatically than the tropics (Parry et al 1988). Some changes are expected to have an impact even within the next two decades, possibly affecting soil temperature, moisture balances, pH, base saturation, organic matter, biological activity, salinity and alkalinity. Effects of increased CO_2 include increased photosynthesis, especially of C3 plants and greater water use efficiency due to closing of stomatal apertures. Higher rainfall may mean greater water availability for irrigation, but also higher run-off and erosion.
Global change processes, whatever their exact magnitude and direction, cannot be ignored by agricultural scientists and require a concerted effort from the research establishment worldwide. The tropical agronomic research establishment is

generally poorly equiped to address these issues and develop strategies to face climatic change.

Symbiosis

Dramatic changes in agricultural production in the coming century will take place in the (sub)tropical belt. Some of these changes will impact on global issues and need to be addressed through a joint effort aimed at understanding and steering these changes to the benefit of mankind. Here lies an enormous and as yet unmet challenge for agricultural science. In this context, developments in temperate agriculture can hardly serve as a guide, while the original objectives of the Green Revolution are being overtaken rapidly. New approaches and new commitments to agricultural research and development are called for.

The role of European agronomists

The basic laws of biomass production are universal in nature. Crop modelers take advantage of this fact and develop the mathematical algorithms that relate environmental factors to the biochemical processes that lead to net production of biomass. For a limited number of intensively studied species these relationships are documented to a point that an overall understanding of the growth determining factors is being approached. For the vast majority of the tropical foodcrops our knowledge is still very scanty while even for the better known species our insights are subject to modification. An example is the relatively recent discovery of the alternative metabolic pathway in C4 plants, the typical grasses of the tropics. There lies an important task, therefore, in making the tools of crop modelling available and extending them to include perennial species and typical cultural practices of the (sub)tropics such as rotations and fallowing, as well as specific disease and pest pressures. European agronomists, armed with the best technology in monitoring and control of pathogens, may play an important role in studying the population dynamics of pests and the epidemiology of diseases and in designing integrated control strategies.
A major effort is needed to better characterise and monitor the land resources of the (sub)tropics. Radiation, evapotranspiration and temperature regimes are increasingly well documented for the tropics as a result of recent international efforts (WMO, FAO). Nevertheless, the number of well-equiped meteorological stations is still very limited and we do not have sufficiently long time series for many locations. This limits the extrapolation of the assessment of potential production levels from point data to larger regions. Modern information technology such as geographical information systems that are readily available in Europe will have to find their way to the (sub)tropics. This implies institutional development and training as well as conceptual efforts to deal with the diversity of the (sub)tropical environments and land use patterns. The quantification of land use and cropping techniques is still in its infancy (Stomph et al 1991).

The role of ESA

Research on tropical issues is currently conducted in an organised fashion by the international agricultural research institutes and a small number of other centres, in close collaboration with national research programmes in developing countries. Broadly speaking, these efforts have been directed first and foremost at genetic improvement and related areas of

pathology, virology and entomology. It is commonly [illegible] that 'research needed to address the many diverse problems of resource degradation and environmental pollution is beyond the capacity of the CGIAR' (TAC 1991:29). Significant scope remains for a closer coupling of European and tropical research. The benefits of such a symbiosis are manifold. European researchers could channel some of their high-tech capacity to link up with partners in the developing and western countries focusing on specific (sub)tropics research issues. This would, among many other things, allow them to counter some of the alleged criticisms currently directed against European agricultural research as being exclusively and 'blindly' production-oriented and one of the causes of current over-production in the EC. Furthermore, such a symbiosis would expose European researchers to new approaches and concepts that could be relevant to their attempts to redesign production systems in the EC. In particular, this applies to some of the low-input concepts of tropical agricultural science in the field of agro-ecology, integrated pest and nutrient management, cropping systems research and watershed management. There may be a special role in this respect for researchers from Mediterranean Europe who work in environments which display similar intricate interactions between rainfall, fertilizer response and weed competition as many parts of the seasonally wet-dry (sub)tropics. The European community recognized the potential of symbiotic interchange when it established the Science and Technology for Development Program (STD) under DG XII which in its latest phase (STD3) receives 111 million ECUs for joint research efforts between European and developing countries in the area of Agriculture and Health.
Sofar, ESA has been organised in subject matter divisions, its primary aim being to bring together European agronomists. The organisation along subject matter or disciplinary lines appears effective in addressing the science of agronomy. We believe, however, that the global dimension of the problems in agriculture to date calls for an international and permanent forum in which such problems can be discussed and addressed. If ESA wishes to take its role in fostering this symbiosis seriously, it must formulate clear initiatives in this area. We cannot expect (sub)tropical scientists to join us as long as we don't make it clear that we share their concerns and are willing to dedicate some of our energies to help solve their problems that are ultimately also ours.

Anderson J 1987 Food Policy 4: 199-212
Altieri M 1987 Agroecology: the scientific basis of Alternative Agriculture Westview Press, Boulder
Bruijn, GH et al 1987 Neth J of Agric Sc 1989 no 37:21-34
Dudal R 1987 Fertilizers & Agriculture 94: 3-15
FAO 1981 Agriculture: Toward 2000 FAO, Rome, Italy
FAO 1989 The state of food and agriculture FAO Agricultural Series No 22 Rome
Goldhammer JG (ed) 1990 Fire in the tropical biota. Ecosystem processes and challenges. Springer Berlin
Giller K & K Wilson 1991 Nitrogen fixation in tropical cropping systems CAB International, Wallingforth UK
Haws LO et al 1983 Comparison of crop productivity in the tropics and in temperate zones. In: Potential productivity of field crops under different environments. IRRI, Los Banos.
Jenkinson D S 1977 Soil Sci Soc Am J 41:912-915
Jordan CF 1987 Amazonian Rainforests - ecosystem disturbance and

recovery Springer, New York
Lal R et al (eds) 1990 Soil degradation Advances in soil science Springer, New York
Linnemann H et al 1979 MOIRA a model of international relations in agriculture. Project Report Amsterdam
Neuenschwander P & W Hammond 1990 Biological control of the cassava mealybug, Phenacoccus manihoti, in Africa: review of the field studies In: Hahn, S Y H Caveness, eds: Integrated Pest Management for tropical root and tuber crops IITA, Ibadan
Parry M et al (eds) 1988 The impact of climatic variations on Agriculture, 2 vols IIASA/UNEP, Kluwer, Dordrecht
Pieri Ch 1989 Fertilité des terres de savannes CF/CIRAD, Documentation Francaise Paris Cedex, France
Sanchez P 1976 Properties and management of soils in the tropics New York, Wiley
Scharpenseel, HW, M Schomaker and A Ayoub (eds), 1990 Soils on a warmer earth Proceedings of an international workshop on Effects of Expected Climate Change on Soil Processes in the Tropics and Sub-Tropics ISSS/UNEP/Elsevier, Amsterdam
Stomph Tj et al 1991 Describing agricultural land use FAO/ITC/LUW, Wageningen
Stoorvogel J et al 1990 Assessment of nutrient depletion in sub-Saharan Africa: 1983-2000 Volume 1: main report Winand Staring Centre report 28, Wageningen
TAC/CGIAR 1991 A review of CGIAR Priorities Washington/Rome
Wit CT de, H et al 1979 Physiological potential of crop production CABO publication no 118, Wageningen