Deutscher Tropentag 2004
Berlin, October 5-7, 2004

Conference on International Agricultural Research for Development

Bridging the gap between integrated and organic agriculture to ensure food security

Janssens[a], Marc, Hartmut Gaese[b], Albrecht Glatzle[c] & Juergen Pohlan[a,d]

a) University of Bonn, Institut fuer Gartenbauwissenschaft, Auf dem Huegel 6, D-53121 Bonn, Germany. E-mail: marc.janssens@uni-bonn.de
b) University of Applied Sciences Cologne – Institut fuer Tropentechnologie, Betzdorfer Str. 2, D-50679 Koeln, Germany. E-mail: hartmut.gaese@fh-koeln.de
c) INTTAS, Loma Plata 1045 – Chaco, C.d.c. 883 Asuncion, Paraguay. E-mail: aglatzle@inttas.org
d) ECOSUR, El Colegio de la Frontera Sur, Antiguo Aeropuerto km 2.5; Apdo. Postal 36, CP 30700 Tapachula, Chiapas, Mexico. E-mail: drjpohlan@excite.com

Summary

Many tropical farming systems are evolving by expanding the cropped area and encroaching on the environment. Most of them are of organic nature and labour unproductive. The developing world is importing countless quantities of cereals, meat and other food, mostly from non-organic farming systems outside the tropics. In fact, the digestive tracts are largely colonised. There are cases where non-subsidised imports can be cheaper than locally produced commodities. Reversing this trend will imply farmer training and a healthy synergism between intensive and organic cultivation techniques. Zero-tillage, enabled by herbicides like glyphosate has gained recognition as a second green revolution step. Seed coating, encompassing whatever fungicides and micro-fertilisers, combined with appropriate seedbed preparation is another such step forward. In horticulture, drip irrigation and plastic tunnels are part of the hinterland of most cities in the tropics. Prophylactic treatment of crops and animals should be based on health stimulating and target specific principles. In animal husbandry, both feed spectrum and genetic base should be appropriate. Most, intensively produced meat is based on cereal and oilseed feed. However, as prolonged feedlots are ecologically questionable, an increased market share of grass-fed animals from improved, energy saving (sub)tropical pastures should be favoured. To enhance efficient use of inputs; (i) the integrated FAO approach for crop health, plant nutrition, water use and soil management should be encouraged, (ii) the target environment receptive, (iii) multiple use of inputs promoted, and (iv) unwanted residual elements remain below organic threshold levels. In either system, inputs should remain within environmentally acceptable standards. Not all natural substances are beneficial to insects, livestock and humans. Emphasis is put upon "vitalising" selected abiotic inputs into ecologically acceptable inputs and/or substrates.

1. Organic farming is not able to mass produce for food security

Today, 842 Mio from the 6 Bio people are undernourished out which 10 in the industrialised world, 34 in the transformation countries and 798 Mio in the developing world (FAO 2004). Among food crises 80% are linked to water shortage. More than 34 Mio ha of land are suitable for further irrigation in Africa (FAO 2004). In 2050 world population is expected to rise up to 9 Bio people. Just for cereal production the acreage should then increase from 676 up to 1016 Mio ha at the present yield level of 3.1 t/ha. If so, we should find a new agricultural area of 3.4 Mio km² without even taking additional fallow land into account! At the 1996 World Food Security summit it was decided to reduce undernourished people by half in 2015. Right now, North and West Africa are stricken by the worst locust plague since 15 years. How to combat such plagues and alleviate today's hunger before it is too late?

Large rural populations dwell in fragile marginal locations with poor soils and erratic climate. Their carrying capacity triggers a vicious circle "Resource degradation – demolition of the means of existence – blocked exit from poverty". Water retention levels in some river systems have reached critical levels (excessive irrigation!). These regions face will be more vulnerable to the effects of climate change. Hence, urban-rural-differential, rural poverty and migration favour "poverty caused resource destruction and over-exploitation". How to supply 90% of mankind living in the tropics without environmental degradation?

2. The environmental issue

2.1. Extensive agriculture

Extensive agriculture is only sustainable at the expense of large acreages of fallow land. For the whole of the Democratic Republic of Congo, one ha of cropped land goes along with 2.3 ha of fallow land i.e. 0.3 ha of fallow/inhabitant. Deforestation is as high as 150000ha/year for the whole of Congo. On average, a field will be cropped during 3 out of 10 years, leaving it 7 years to idleness. This system is consuming a lot of land, hence it is infringing on the environment due to the demand rising from a booming population. Intensifying agriculture is the only way to reducing the environmental abuse through agricultural mining (Janssens & Pohlan 2000). Sound organic agriculture with restricted use of external inputs will be able to alleviate the environmental issue only if the world population would diminish.

The sole option to liberate the necessary land for carbon sequestration would be the intensification of agricultural production on some of the better lands by increased fertiliser inputs. Increasing the fertiliser use in the developing world (without China) by 20%, would yield a net benefit in the carbon budget of between 80 and 206 Mt yr^{-1} depending on the carbon sequestration rate assumed for the regrowing forest (Vlek *et al.* 2004).

2.2. Integrated agriculture

Studies in the semi-arid Central Chaco of Paraguay have shown a tremendous potential of productivity increase per unit area in cattle grazing systems when the spontaneous vegetation is replaced by improved pastures with selected and persistent grasses and improved genetic and hygienic conditions of the grazing animals. The approximately 20-fold increase in area productivity can be attributed by the factor 10 to the improved herbage availability and by the factor 2 to the genetic and hygienic improvement of the animals (Glatzle 1999a). The productivity per unit are in cow calf grazing systems in the Central Chaco of Paraguay could be increased from 5-10 kg liveweight increment/ha/a up to 154 on improved pasture (Dück 1997, Neufeld 2001 in Glatzle 2004). Typical examples of a semi-extensive integrated land use, predominantly in dryer areas with a wide range of rainfall patterns, are ley-farming systems, rotation between a cropping and grazing phase at one particular site. Ley-farming systems range from low input weedy fallow and crop residues grazing to rather intensive reseeding of leguminous or grass pastures after every cropping phase of one to several years. A successful ley-farming system (low input, highly productive) has been developed in Australia and adopted to various countries in the developing world: Leguminous pastures (with annual Medics, *Ornithopus*, *Stylosanthes hamata* or *Alysicarpus vaginalis*), which spontaneously regenerate after a short cropping phase from the seed bank in the soil (Glatzle 1989). In Mexico, it was possible to reduce the incidence of the coffee borer (*Hypothenemus hampei*) by intercropping coffee with *Canavalia* as a cover-crop (Pohlan 2002).

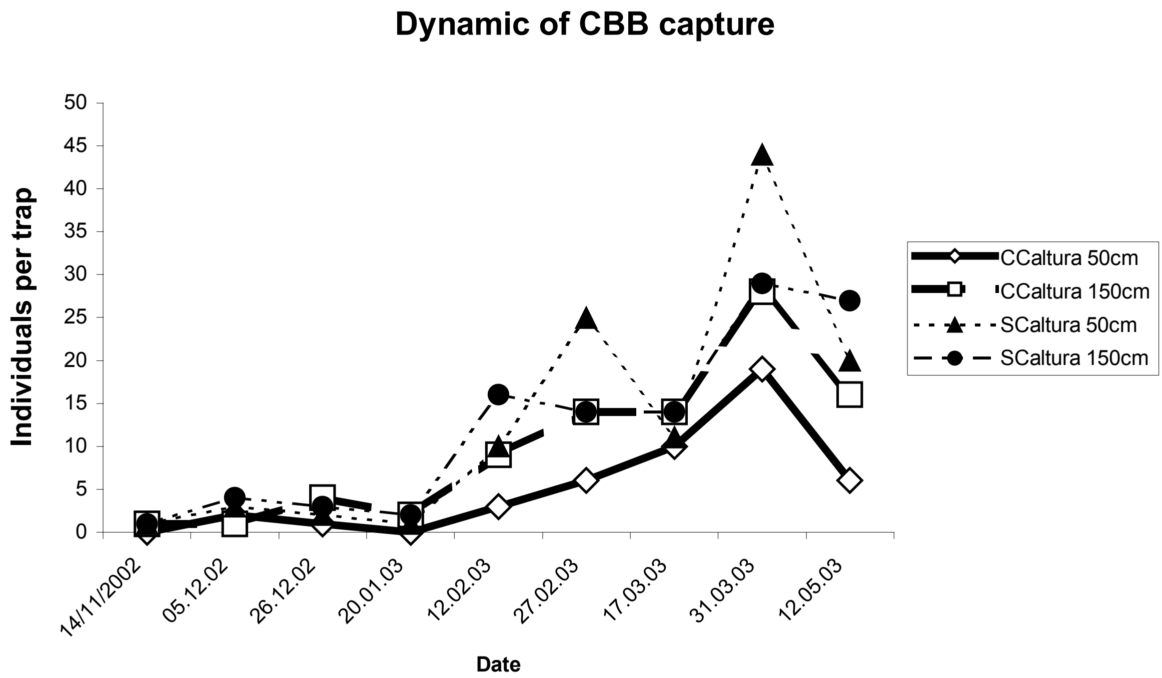

Figure 4: Effects of *Canavalia* cover (CC) and weed cover (SC) on the dynamic of coffee borer (CBB) capture on height's of 50 and 150 cm (Pohlan 2002).

3. The biomass management

3.1. Zero-tillage

Sufficient ground cover with biomass (crop residues, green manure or even weedy biomass) is crucial for a successful zero-tillage management: Increased soil humidity, less chance of weed establishment, improved soil structure and soil organic matter content).

Figure 2: Zero-tillage in Brazil: Soya bean harvesting and direct maize sowing

Landers (2001) gives technical details of how to manage land under zero-tillage cultivation in Brazil and other Latin-American countries. Using soybean, beef and maize, the improvement in terms of land conservation is impressive. Surplus profit can be as high as +85% w.r.t. conventional tillage. In Figure 2, 31 soybean harvesters are preceding 12 tractors, which are direct sowing maize in one go under zero-tillage cultivation technique (Sorriso, MT, Brazil, Grupo Pinesso).

When mono-cropping peanut over 12 years in Paraguay, average yield reached 1775 kg/ha without green manure as an intercrop and 1880 with intercrop (*Carthamus, Sorghum, Melilotus alba* und *Avena strigosa).* When rotating peanut with cotton the corresponding yields were 2103 kg/ha of peanut without intercrop and 2105 with (Giesbrecht 2001).

3.2. Biomass management in uni-modal tropical savannah woodland

Annual litter fall is a good indicator of biomass dynamics in agroforestry systems (Table 1).

Table 1. Litter fall & Biomass in Haut-Ouémé (Benin)-Monomodal rainfall (t/ha.year)

Village	LUS	L_f	L_t	L_w	L_t+L_w	B_t	$(L_t+L_w)/B_t$
Serou 9N1E	**Forest**	6.31	9.02	0.20	9.22	207	0.045
	Cashew nut	3.87	4.55	2.80	7.35	29	0.253
Dogué 10N2E	**Forest**	3.20	4.10	0.80	4.90	109	0.045
	Cashew nut	1.93	2.65	3.90	6.55	35	0.187

Source: Janssens *et al.* (2004); B_t=total standing biomass; L_t=Litter fall over one year in t dry matter/ha; L_f=The leaf fraction within the litter in t/ha; L_w=annual weeds increase;

The litter fall, including weeds, in the forest systems is inferior to 5% of the total standing biomass. On the contrary it amounts up to 19-25% in the cashew orchards.

3.3. Biomass management in bimodal cocoa based forest area (Table 2)

In the cocoa based systems, annual export of cocoa bean was inferior to 0.5 t dry cocoa beans/ha/year in all shaded cases and inferior to 1 t in the non-shaded treatment, which is equivalent to less than 2/1000 or 2% from total biomass, respectively. Even the unshaded treatment has a sustainable character if it were not for the higher need for insecticides.

Table 2. Litter fall and biomass in Southern Cameroon- Bimodal rain (Unit=t/ha.year)

Sub-region or orchard type	L_f	L_t	L_w	L_t+L_w	B_t	$(L_t+L_w)/B_t$	Exported cocoa
Ebolowa	5.80	8.10	1.40	9.48	406	0.023	0.0012
Mbalmayo	7.10	9.70	1.00	10.73	390	0.027	0.0013
Yaoundé	10.00	14.20	1.20	15.41	413	0.037	0.0012
Cocoa under natural forest	6.80	9.40	1.30	10.69	340	0.031	0.0015
Non-shaded cocoa orchard	3.90	4.80	3.30	8.08	48	0.168	0.0208

Source: Janssens *et al.* 2004

3.4. The crop choice: annual vs. perennial crops

In future, tropical agriculture will evolve more and more towards perennial crops, just because the latter ones are more input efficient, produce more biomass year round and finally contribute to a positive microclimatic change (Janssens & Subramaniam, 2000).

Table 3. Major Agricultural Categories and Functions (partim)

Category	Subcat.	Annual crops *(partim)*	Permanent crops *(partim)*
Carbo-hydrates	Starch	Cereals, Roots & Tubers	Plantain, Bread tree, Treculia africana, Chestnut,
	Sugar	Sugar beet, Sugar cane	Borassus flabellifer, Sugar maple, Sugar palm,
Protein		Pulses, Pigeonpea	Avocado, Baobab, Tamarind, Caroub tree,
Lipid		Peanut, Soyabean, Sesame, Flax	Oil palm, Coconut, Olive, Karite, , African pear,

Source: Janssens, M.J.J. & Subramaniam, B. 2000.

In fact, it is possible to find perennial equivalent crops for all plant categories, including fuel wood, fodder and grazing crops, fibre, rubber, insecticidal crops, spices/flavours, essential oils/perfumes, dyes, vegetables and fruits (Table 3).

3.5. The crop rotation choice: multiple cropping/catch crops

Multiple cropping per year is perhaps not so efficient as thought. Indeed, each mechanised cultivation step requires energy, going from 73 MJ/ha for each pesticide spraying, over 240 for howing up to 1180 for plowing (20 cm), considering a fuel equivalent of 47.8 MJ/L (Kitani *et al.* 1999). Leguminous pastures produce a pronounced effect on the yield of the subsequent crop in a ley-farming system. As table 4 shows, even under semi-arid conditions in the Chaco, leguminous pastures are capable of increasing yield and cash income of the subsequent Sorghum crop which responds favourably to accumulated soil Nitrogen.

Table 4. Effect of leguminous pasture on subsequent crop

Previous crop	Sorghum corn yield (kg/ha)	Sorghum silage yield (t DM/ha)
Green fallow	1510	3.8
Leguminous pasture	1950 (+440)	7.0 (+3.2)

Source : Glatzle (1999b)

4. Crop demand driven agriculture

4.1. Mineral requirements

To ensure food security it will be necessary to accept compensating minerals exported through the harvested products with fertiliser imports, either organic or mineral, from outside the farming system. The real issue is whether (i) these imports are efficiently used and (ii) the imported amounts do not exceed the crop demand (Roy *et al*. 2002). To the usual fertiliser plan one ought to include all elements coming from other agro-chemicals. By applying a Bordeau pulp (mixture) one should not exceed the crop requirements in S or Cu. With Mancozeb again one should not exceed the requirements in Manganese or Zinc.

4.2.Input efficiency through precision, multiple use and multiple purpose

Water is like a capital, which can only be productive when turning around. Multiple use of water in Asian farming systems is well documented, whereby fish pond water is used for irrigation. The high water requirements for rice growing will become critical even before 2050. Tree crops, soil and biomass conservation measures will increase water efficiency.

Some mineral fertilisers have interesting herbicidal properties e.g. Calcium Cyanamid can be used not only as fertiliser but also as herbicide or molluscicide. Seed coating protects the seed but also of provides enough micro-elements to ensure a good start after germination. Adding mineral fertilisers like ammonium sulphate to some herbicides like glyphosate will give a synergistic effect. Hence, the amount of herbicide/ha/a can be reduced and by the same token some of the sulphur and nitrogen demand has been met. A proper seedbed preparation together with precision farming will compound the effects of all these inputs.

4.3.The energy question

The energy costs for transporting organic material for field improvement are high. If one were to transport by hand e.g. 10 t of compost over 1 km in order to fertilise 1 ha it would require 500 turns i.e. 500 km with load on the head and 500 km without load, together 1000 km! Compromises will have to be accepted between on-farm composting and *in situ* composting. Energy efficient farming should become a major concern. The energy requirements for zero-tillage are less than for conventional tillage (Table 5). Reducing the proportion of annual crops in our farming systems will be another way of saving on energy.

Table 5. Energy requirements of different tillage systems (Partim)

Tillage system	Implements + cultivation steps	Overall Energy (MJ/ha)*
Conventional tillage	Moldboard plow + disk harrow or cultivator (2 passes) + drill	2200 +/- 350
	Chisel plow + disk harrow or cultivator + drill	1100 +/- 200
No tillage	Disk planter	300 +/- 50
	Coulter drill	450 +/- 75

Source: Kitani *et al*. (1999). * Fuel equivalent is 47.8 MJ/L

5. Crop x animal synergism

Persistent herbaceous tropical legumes, predominantly adapted to sandy soils, and the leguminous fodder shrub *Leucaena*, well adapted to soils with loamy texture, usually produce a considerable increase in live weight gains per unit area. This is due to higher growth rate per animal and higher tolerable stocking rates (animals per ha). The input of legume born Nitrogen into the grazing system improves herbage quality considerably (more protein) and increases growth rate of associated otherwise nitrogen deficient grasses (Table 6).

Table 6. Live weight increase of oxen in a Pangola (*Digitaria decumbens*) pasture with and without legumes

	Number of years after sowing legumes				
	1	2	3	4	5
Leguminous cover* of pasture (%)	4	8	13	29	34
Number of oxen/ha	1.0	1.3	1.3	1.0	1.4
Live weight increase (kg ha^{-1} a^{-1})					
With legumes	292	270	333	284	320
Without legumes	284	231	301	227	271
Difference	8	39	32	57	49

Source: Glatzle (1999b). * Of initial 12 legumes, *Alysicarpus vaginalis* (18%), *Lotononis* (9%), *Stylosanthes guianensis cv. Oxley* (8%) and *Macroptilium atropurpureum* (Siratro) (7%) were persistent

The introduction of the leguminous fodder tree *Leucaena leucocephala* in permanent grassland has the potential of doubling the productivity per unit area in tropical grazing systems. Furthermore, it clearly represents an additional Carbon sink in pastures, capable of sequestering significant amounts of the greenhouse gas Carbon Dioxide (Table 7, Figure 3).

Figure 3: Young bulls grazing on a *Leucaena* enriched panic pasture

Table 7. Live weight increase of young bulls from 15.7.03 until 15.4.04 in *Leucaena* enriched pastures (*Panicum maximum* cv. Gatton) - Estancia Rio Verde (Paraguay)

Pasture type	Live weight increase of bull-calfs (kg/ha)*	Animal density TLU/ha
Panicum maximum cv. Gatton	211	1.1
P. maximum cv. Gatton + *Leucaena*	476	1.7

Source: Glatzle (2004)

The young bulls grazing in the *Leucaena* paddock had been inoculated with the Mimosin degrading rumen bacteria, *Synergistes jonesii*. Mimosin is an anti-nutritive to toxic substance contained in *Leucaena* leaves, which otherwise do present excellent forage quality characteristics. Mimosin serves as a Carbon and Energy source for *Synergistes*.

6. Vitalising abiotic inputs

The length of a fallow period should be long enough to neutralize all possible side effects from agrochemicals. All agro-chemical residuals should be broken down below an adopted threshold value. To the contrary, most chemical inputs are excluded in organic agriculture.

Compost can be enriched with soil worms into lumbricomposts (Pohlan 2002), with mycorrhizae, nitrogen fixing bacteria and even mineral fertilisers as e.g. lime, DAP. The input sequence is of importance. The living inocula will be added only after the fresh organic material has been mixed gradually with lime. Only then worms will be added, followed by mycorrhizae and bacteria. DAP will be mixed towards the end. Effluents of the composting heaps will be collected as they are known to act efficiently against diseases and pests. Especially, the highly water soluble saponins, known for their insecticidal and fungicidal properties, are to be collected at the very beginning of the composting.

Table 8. Multinutritionnal lickstone manufactured in Laos

Components	% (Wt)	Price (%)
Rice bran	45	53
Urea	10	23
Kitchen salt	5	4
Bone meal	5	6
Cement	10	8
Lime	5	6
Clay	20	0

Source:C. Kayouli 1994.

It is contended that whatever abiotic inputs are welcome in so far they are: (i) energy saving to the farming system, (ii) assimilated by an appropriate organic environment and (iii) harmless to human beings for the quantities used, both on the production side as on the consumer side. Mineral fertilisers like urea, phosphorus can be made available to the crops by grazing animals which are given access to multinutritionnal lickstones (Table 8).

In fact, whatever mineral fertiliser, herbicide, insecticide, fungicide, nematicide or any other agrochemical should only be allowed if (i) there is enough standing biomass, (ii) if the humus content of the soil is high enough and (iii) if the buffer capacity of the corresponding landscape, including its biodiversity, is satisfactory. Precise ceiling limits for the use of agrochemicals and irrigation are to be articulated for each agro-ecological zone.

7. The farming system choice: precision, conservation, vitality

Here are the conditions for ensuring food security in the long run:

1. Bridging the gap between organic and integrated, environmentally responsible farming requires: (i) Integrated pest control in plant production systems, (ii) Improved water provision and water use, (iii) Intensification of production systems in phase with local knowledge, primarily under favourable, stable ecosystems to decrease the pressure on marginal, fragile ecosystems (iv) Resource saving technologies and technology transfer for improved agriculture and pasture management and (v) Innovative security systems
2. Along with this new type of farming one requires an eco-risk zoning methodology: Identification, quantification, and monitoring of degradation factors, resource use and environmental impact in the different agro-ecosystems, including peri-urban and semi-arid regions, within the spatial reference of watershed division (World Development Report 2003 and BMZ, 2002). Early alert systems on climatic risks and crisis management units.
3. The strategies for sustainability are governed by efficiency, productivity, consistency, recycling, sufficiency and resource reduction, and finally by GIS supported eco-risk-zoning methodologies (BMZ, 2002). Irrigation and water saving management are pivotal to the further development of all watershed basins. Genetic adaptation of animals and plants for performance increase under input efficient environments should be encouraged. Good farming will vitalise abiotic elements into an organic rich agro-environment. Precision farming and conservation agriculture will bridge this upcoming food gap.

References

BMZ 2002. Environment, Poverty and Sustainable Development – Topic Papers on the Environment & Sustainable Utilisation of Natural Resources in Development Co-operation, Bundesmin. für wirtschaftliche Zusammenarbeit & Entwicklung (BMZ). Bonn

FAO 2004. Summary of Food and Agricultural Statistics. Rome, Italy www.fao.org/DOCREP/006/Y5085E/Y5085E00.HTM.

GAESE, H. 1998: Die Entwicklung der Weltbevölkerung, die Ernährungsproblematik und der technische Fortschritt, in UmweltWirtschaftsForum, 6. Jahrg. (Springer-Verlag)

GIESBRECHT, W. (2001): Versuchsbericht der Versuchsstation Isla Poi. Servicio Agropecuario Loma Plata 125pp

GLATZLE, A. (1989): Standortgerechte Landbewirtschaftung durch Leyfarming mit selbstregenerierenden Leguminosen. Tropenlandwirt 90, 27-41

GLATZLE, A. (1999a): Wie nachhaltig ist die Nutzung von anthropogenem Grasland im Chaco von Paraguay? In H. Seifert, P. Vlek & H. Weidelt (eds.): Stabilisierung und nachhaltige Entwicklung land- & forstwirtschaftlicher Systeme in den Tropen. Göttinger Beiträge zur Land- und Forstwirtschaft in den Tropen und Subtropen, Heft 133, 113-117

GLATZLE, A. (1999b): Compendio para el Manejo de pasturas en el Chaco. El Lector, Asunción

GLATZLE, A. (2004): Mejoramiento de Forrajes Tropicales: Gramíneas y Leguminosas. En Federación Latinoamericana de Semillas (ed.): Conferencias y Resúmenes de Trabajos Presentados, XIX Seminario Panamericano de Semillas, Asunción 113-122

JANSSENS, M.J.J. & SUBRAMANIAM, B. 2000. Long-term Perspectives of Fruit and other Tree Crops in the New Century. In: Proc. 2nd Conf. (Sub)trop. Fruits, Eds. M. Blanke & J. Pohlan. Acta Hort. 531, ISHS, pp. 23-27

JANSSENS, M.J.J. and POHLAN, J. 2000. Agricultural Mining in Ethiopia and Congo-Kinshasa. In: Deutscher Tropentag 2000 - International Agricultural Research: A Contribution to Crisis Prevention. Oct. 11-12, 2000. University of Hohenheim

JANSSENS, M.J.J., ZHIXIN DENG, SONWA, D., Torrico, J.C., MULINDABIGWI, V. & POHLAN, J. 2004. Relating agro-climax of orchards to eco-climax of natural vegetation. Proc. 7th International Symposium on Modelling in Fruit Research and Orchard Management, Acta-ISHS, Copenhague, Denmark (In press)

KAYOULI, C. 1994. Increasing utilization of locally available feed resources for cattle & buffaloes. 1st Adv. Mission to Lao People's Dem. Rep. TCP FAO-TCP/LAO/4451 (T).

KITANI, O., JUNGBLUTH, T., PEART, R.M. & RAMDANI, A. 1999. CGIR Handbook of agricultural engineering. Vol. V. Energy and Biomass Engineering. American Society of Agricultural Engineers, St Joseph, Michigan, USA

LANDERS, J.N. 2001. Zero tillage development in tropical Brazil: The story of a successful NGO activity. FAO Agricultural Services Bulletin nr 147, FAO, Rome

POHLAN, J. 2002: Complementary effects of weeds in coffee plantations in Chiapas, Mexico. Z. PflKrankh. PflSchutz, Sonderh. XVIII, 175-182

POHLAN, J. (Ed.) 2002: México y la cafeticultura chiapaneca – reflexiones y alternativas para los cafeticultores. Aachen, Verlag Shaker, Agrarwissenschaft, 386 paginas.

ROY, R.N., MISRA, R. V. & MONTANEZ, A. 2002. Decreasing reliance on mineral nitrogen – Yet more food. Ambio Vol. 31 No. 2:177-183

VLEK, P.L.G., RODRIGUEZ-KUHL, G. & SOMMER, R. 2004. Energy use and CO_2 production in tropical agriculture and means and strategies for reduction or mitigation. Environment, Development and Sustainability 6: 213-233

WORLD BANK 2003. World Development Report 2003: Sustainable Development in a Dynamic World, The International Bank for Reconstruction and Development/The World Bank, 1818 H Street, N.W. Washington D.C.