LOW-EXTERNAL INPUT FARMING SYSTEM-STRATEGY FOR ENVIRONMENTAL PROTECTION

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ABSTRACT

Conventional (high input) technologies in crop production involve much intensive tillage systems, artificial fertilizers application, and substantial increase in the use of pesticides. The specialization of production units has led to the image that agriculture is a modern miracle of food production. Evidence indicates, however, that excessive reliance on monoculture farming and agroindustrial inputs, such as capital-intensive technology, pesticides, and chemical fertilizers, has negatively impacted the environment and rural society.The agroecological objective is to provide a balanced environment, sustained yields, biologically mediated soil fertility and natural pest regulation through the design of diversified agroecosystems and the use of low-input technologies. The process of converting a conventional crop production system that relies heavily on systemic, petroleum-based inputs to a diversified agroecosystem with low-inputs is not merely a process of withdrawing external inputs without compensatory replacement or alternative management. Considerable ecological knowledge is required to direct the array of natural flows necessary to sustain yields in a low-input system.

INTRODUCTION

Most scientist today would agree that conventional modern agriculture faces an environmental crisis. Serious problems such as land degradation, salinization, pesticide pollution of soil, water and food chains, depletion of ground water, genetic homogenity and associated vulnerability raise serious question regarding the sustainability of modern agriculture. The causes of the environmental crisis are rooted in the prevalent socioeconomic system, which promotes monocultures and the use of high input technologies and agricultural practices that lead to natural resources degradation(1). Such degradation is not only an ecological process but also a social, political and economic process. While productivity issues represent part of the problem of natural resource degradation, addressing the problem of agricultural production must go beyond technological issues and include attention to social, cultural and economic issues that account for the crisis as well. Today as more and more farmers are integrated into international economies, imperatives to diversity disappear and monocultures are rewarded by economies of scale. In turn, lack of rotations and diversification take away key self-regulating mechanisms, turning monocultures into highly vulnerable agroecosystems dependent on high chemical inputs.

Any crop production system can be subdivided, on the basis of component elements, into inputs, biological processes and depletions or net losses. The biological processes include photosynthesis, genetics of the crop in terms of its adaptation to the soils and climate and resistance to pests and diseases, biological nitrogen fixation, nitrogen cycling in the soil, phosphorus uptake by mycorrhizal fungi associated with roots, plant defence by plant-associated microorganisms and natural enemies of insect pests and soil sanitation by the natural soil microbiota(11). The inputs include the fertilizers, water, where irrigation is practiced, pesticides, labour and energy. The depletions or net losses are largely earth resources and include the organic matter and mineral nutrients contents of the soil, water reserves and water quality, soil lost through erosion and fossil fuels.

The relative contributions of these three component elements to crop production on any given farm vary with the farming system(13). Some systems attempt to reduce inputs and make greater use of biological processes; other use more inputs and depend less on biological processes. These components refer only to those elements that are involved directly in crop production and do not include broader considerations such as food safety.

CONVENTIONAL FARMING SYSTEM

The technologies allowing the shift toward monoculture were mechanization, the improvement of crop varieties, and the development of agrochemicals to fertilize crops and control weeds and pests. Government commodity policies these past several decades encouraged the acceptance and utilization of these technologies. As a result, farms today are fewer, larger, more specialized and more capital intensive. At the regional level, increases in monoculture farming meant that the whole agricultural support infrastructure (i.e. research, extension, suppliers, storage, transport, markets, etc.) has become more specialized. Conventional (high input) technologies in crop production involve much intensive tillage systems, artificial fertilizers application, and substantial increase in the use of pesticides(3). The loss of yields due to pests in many crops (reaching about 20-30% in most crops), despite the substantial increase in the use of pesticides (about 500 million kg of active ingredient worldwide) is a symptom of the environmental crisis affecting agriculture. It is well known that cultivated plants grown in genetically homogenous monocultures do not possess the necessary ecological defense mechanisms to tolerate the impact of outbreaking pest populations. Modern agriculturists have selected crops for high yields and high palatability, making them more susceptible to pests by sacrificing natural resistance for productivity. On the other hand, modern agricultural practices negatively affect pest natural enemies, which in turn do not find the necessary environmental resources and opportunities in monocultures to effectively and biologically suppress pests. The great problems occur in final products, pesticides and fertilizers residues in food. These residues cause the great problems in human health as well.

Emerging biotechnological approaches do not differ as they are being pursued to patch up the problems (e.g. pesticide resistance, pollution, soil degradation, etc.) caused by previous agrochemical technologies promoted by the same companies now leading the bio-revolution. Transgenic crops developed for pest control closely follow the paradigm of using single control mechanism (a pesticide) that has proven to fail over and over again with insects, pathogens and weeds. Transgenic crops are likely to increase the use of pesticides and to accelerate the evolution of 'super weeds' and resistant insect pests(2).

The 'one gene-one pest' approach has proven to be easily overcome by pests that are continuously adapting to new situations and evolving detoxification mechanisms. There are many unanswered ecological questions regarding the impact of the release of transgenic plants and microorganisms into the environment. Among the major environmental risks associated with genetically engineered plants are the unintended transfer to plant relatives of the 'transgenes' and the unpredictable ecological effects.

ENVIRONMENTAL PROBLEMS CAUSED BY CONVENTIONAL FARMING SYSTEM

The specialization of production units has led to the image that agriculture is a modern miracle of food production. Evidence indicates, however, that excessive reliance on monoculture farming and agroindustrial inputs, such as capital-intensive technology, pesticides, and chemical fertilizers, has negatively impacted the environment and rural society. Most agriculturalists had assumed that the agroecosystem/natural ecosystem dichotomy need not lead to undesirable consequences, yet, unfortunately, a number of "ecological diseases" have been associated with the intensification of food production. They may be grouped into two categories: diseases of the ecotope, which include erosion, loss of soil fertility, depletion of nutrient reserves, salinization and alkalinization, pollution of water systems, loss of fertile croplands to urban development, and diseases of the biocoenosis, which include loss of crop, wild plant, and animal genetic resources, elimination of natural enemies, pest resurgence and genetic resistance to pesticides, chemical contamination, and destruction of natural control mechanisms. Under conditions of intensive management, treatment of such "diseases" requires an increase in the external costs to the extent that, in some agricultural systems, the amount of energy invested to produce a desired yield surpasses the energy harvested.

LOW-EXTERNAL INPUT FARMING SYSTEM

From a management perspective, the agroecological objective is to provide a balanced environment, sustained yields, biologically mediated soil fertility and natural pest regulation through the design of diversified agroecosystems and the use of low-input technologies(15,19). The strategy is based on ecological principles that lead management to optimal recycling nutrients and organic matter turnover, closed energy flows, water and soil conservation and balanced pest-natural enemy populations. The strategy exploits the complementarities and synergisms that result from the various combinations of crops, trees and animals in spatial and temporal arrangements. These combinations determine the establishment of a planned and associated functional biodiversity which performs key ecological services in the agroecosystem(24).

The process of conversion from a high-input conventional management to a low-external input management is a transitional process with four marked phases:

(a) Progressive chemical withdrawal.

(b) Rationalization and efficiency of agrochemical use through integrated pest management (IPM) and integrated nutrient management.

(c) Input substitution, using alternative, low-energy input technologies.

(d) Redising of diversified farming systems with an optimal crop/animal integration which encourages synergisms so that the system can sponsor its own soil fertility, natural pest regulation, and crop productivity.

During the four phases, management is guided in order to ensure the following processes:
(a) Increasing biodiversity both in the soil and above ground
(b) Increasing biomass production and soil organic matter content
(c) Decreasing levels of pesticide residues and losses of nutrients and water components
(d) Establishment of functional relationships between the various plant and animal farm components
(e) Optimal planning of crop sequences and combinations and efficient use of locally available resources.

The optimal behavior of agroecosystems depends on the level of interactions between the various biotic and abiotic components. By assembling a functional biodiversity, it is possible to initiate synergisms which subsidize agroecosystem processes by providing ecological services such as the activation of soil biology, the recycling of nutrients, the enhancement of beneficial anthropods and antagonists, and so on. In other words, ecological concepts are utilized to favor natural processes and biological interactions that optimize synergies so that diversified farms are able to sponsor their own soil fertility, crop protection and productivity. By assembling crops, animals, trees, soils and other factors in spatial/temporal diversified schemes, several processes are optimized. Such processes (i.e. organic matter accumulation, nutrient cycling, natural control mechanisms, etc.) are crucial in determining the sustainability of agricultural systems.

Agroecology takes greater advantage of natural processes and beneficial on farm interactions in order to reduce off-farm input use and to improve the efficiency of farming systems. Technologies emphasized tend to enhance the functional biodiversity of agroecosystems as well as the conservation of existing on-farm resources. Promoted technologies are multi-functional as their adoption usually means favorable changes in various components of the farming systems at the same time. For example, legume based crop rotations, one of the simplest forms of biodiversification can simultaneously optimize soil fertility and pest regulation. It is well known that rotations improve yields by the known action of interrupting weed, disease and insect lifecycles. However, they can also have subtle effects such as enhancing the growth and activity of soil biology, including vesicular arbuscular mycorrhizae (VAM), which allow crops to more efficiently use soil water nutrients.

CHANGES IN TILLAGE SYSTEM

In conventional systems of tillage, tractors and implements make between 7 and 16 passes over the field for land preparation. In contrast, conservation tillage systems greatly reduce the number of tractor and implement passes required, and leave a protective blanket of leaves, stems and stalks from the previous crop on the soil surface[6,14,15]. Less tillage means less soil compaction and lower fuel and labour costs, less wear and tear of the tractor and implements, and more time available for other activities. Moreover, the surface cover of crop residues shields the soil from heat, wind, and rain, keeps the soil cooler, and cuts down moisture losses by evaporation.

Conservation tillage systems reduce efforts spent on intensive weeding [15]. Every time a farmer tills or ploughs to control weeds, he makes the soil more vulnerable to erosion, which is the most significant environmental problem. With conservation tillage a grower relies more on weed control by crop rotation, cover crops and mulch covers. If herbicides are to be used, then conservation tillage systems allow the use of less harmful products than those used in most conventional farming operations. They are generally low in toxicity to wildlife and beneficial insects, and break down so quickly that there is minimal risk to water quality.

Table I. Effect of tillage systems on grain yield of maize and soyabean

Tillage systems	Maize			Soyabean	
	t/ha	Harvest index	%	t/ha	%
Conventional tillage (CT)	7.11	0.52	100.00	3.920	100.00
Reduced tillage (RT)	5.44	0.52			
No- tillage (NT)	5.25	0.55			
Total reduced tillage	5.34	0.54	75.10		
Mulch tillage (MT) > 30% of mulch	5.21	0.52			
No-tillage (NT)	5.50	0.56		2.550	65.05
Total conservation tillage systems	5.36	0.54	75.38	2.375	60.59

Disadvantage of this tillage systems is yield decrease of crops (Table I). But at the same time the inputs of such production system decrease as well, not mention the benefits in the environment. Some crop cultivars are adapted for less favourable conditions in occuring environment. Low-input cultivars are less sensitive than high-input ones, and they give better yield than high-input cultivars of winter wheat (Table II). The choice of crops and their cultivars used in such farming system is very inportant.

There is no fixed recipe for conservation tillage. Each farm is different, and the first year is always the most difficult. The farmer may need to reduce tillage operations gradually, rather than switch all at once to no tillage. The build-up of a crop residue cover takes time, and soil organic matter takes several years to increase. Furthermore, farmers need to understand how and why the new systems works-so as to be able to make the most of conservation tillage and avoid potential pitfalls.

Table II. Effect of low-input technology on grain yield of winter wheat (t/ha)

Tillage systems	N level	Low-input cultivars				High input cultivars		Average	
		Lasta	Pobeda	Francuska	NS rana 5	Pesma	NS rana niska		
CT	60 kg/ha	6.195	5.379	5.507	5.647	4.493	4.060	5.213	
	control	4.462	4.282	4.954	4.581	4.295	3.011	4.264	4.738
MT	60 kg/ha	4.390	3.887	4.685	3.840	4.318	2.827	3.991	
	control	3.125	2.665	3.861	3.084	3.076	2.344	3.026	3.508
NT	60 kg/ha	4.239	3.730	4.096	3.239	2.907	2.578	3.464	
	control	3.026	2.530	3.505	2.596	2.408	1.929	2.666	3.065
Average		4.941	4.332	4.763	4.242	3.906	3.155	4.223	

CT-conventional tillage
MT-mulch tillage
NT-no-tillage

CHANGES IN FERTILIZERS USE

Reduction and, especially, elimination of agrochemical require major changes in management to assure adequate plant nutrients. The first step in transition from conventional to integrated nutrient management is reduction of chemical fetilizers (Table III). Reduced amount of N-fertilizer in combination with reduction of tillage increase nutrient content in the soil and better eficiency use.

Table III. Effect of low-input technology on nitrogen content (ppm) in winter wheat (0-60cm in depth)

Tillage systems	N level	NH_4-N	NO_3-N	Total N
CT-Conventional tillage	120 kg/ha	24,50	2,62	27,12
	60 kg/ha	6,12	1,75	7,87
	control	11,38	3,50	14,88
RT- Reduced tillage	120 kg/ha	9,62	4,38	14,00
	60 kg/ha	9,72	8,75	18,47
	control	5,75	2,62	8,37
NT- No- tillage	120 kg/ha	39,38	13,13	52,51
	60 kg/ha	19,25	7,00	26,25
	control	7,87	4,38	12,25

Alternative sources of nutrients to maintain soil fertility include manures, sewage sludge and other organic wastes, legumes in cropping sequences and green manure[12].
Green manure crops are crops which are grown to be turned under to increase soil fertility. Leguminous green manure crops, those which can make nitrogen fertilizers from atmospheric nitrogen, can offer a tremendous number of advantages:
1) They provide large quantities of nitrogen for the soil.
2) They add many tons of organic matter to the soil, thereby improving topsoil depth, water-holding capacity, nutrient content, friability, and texture of the soil.
3) Since the green manure crop grows in place, it presents no transportation problems, in contrast to either compost or chemical fertilizers.
4) Green manure crops require absolutely no capital outlay after the initial purchase of seed. They require no chemical inputs, so dependency on outside sources of fertilizer, nutrients, and pesticides is reduced.
5) Green manure crops can shade the soil up to eleven months out of the year, a factor extremely important for preservation of soil moisture and organic matter.
6) The cover they provide for the soil protects the soil from wind or water erosion.
7) Green manure crops provide generous amounts of high protein fodder for animals, which can be especially valuable if it is available during the last months of the dry season (since fodder at this time of year is the limiting factor in traditional animal-raising in much of the third world).
8) Some green manure crops provide human food, including various kinds of edible beans, peas, and pods.
9) Green manure crops can provide a cash income, by selling firewood, food or feed (and maybe seed).
10) They often provide an incentive for people to abandon harmful traditional practices, such as burning crop residues or letting animals loose in the dry season to devour everything in sight.

11) Some green manures can control weeds when intercropped with grains, eliminating costly weeding operations.

Something like 30% of all the increases in harvests achieved by small farmers in the third world during the last three decades has been achieved through the use of chemical fertilizers. Should petroleum prices shoot up once again, as could easily happen sometime in the next decade, prices of chemical fertilizers could easily become too expensive to be economically feasible for use with traditional basic grains.

It might be useful to compare composting with the use of green manure crops:

1) Compost merely decomposes the organic matter one already has, whereas a green manure crop can often add over 40 tons of additional organic matter per hectare. Inasmuch as organic matter is often in short supply on villagers' farms (or is already being recycled), this is an important consideration.

2) At best, compost will return to one's field about 98% of the nitrogen one started out with. A green manure crop, however, will add considerable quantities of new nitrogen to the system.

3) A compost heap takes a tremendous amount of work, as anyone who has made one can attest. Though compost will often pay in a vegetable garden, it is not economical when used on basic grain crops such as corn or wheat. On the other hand, although a green manure crop takes a bit of labor to plant (using a dibble stick) and a fair amount of labor to incorporate, it takes much less labor then a compost heap. And in some cases where the green manure crop is intercropped among traditional crops (such as corn, sorghum, soyabean), it covers the ground so well that one or even two weeding operations can be eliminated, thereby actually bringing a net savings in labor.

4) Compost heaps require water, so they are made near a water supply but at a distance from where they will be applied. Green manure crops take advantage of available rain water, and are planted where they will be used.

5) Compost cannot be used as a food source, either for animals or humans.

BIODIVERSIFICATION OF AGROECOSYSTEMS

Agroecologists are now recognizing that intercropping, agroforestry and other diversification methods mimic natural ecological processes, and that the sustainability of complex agroecosystems lies in the ecological models they follow. By designing farming systems that mimic nature, optimal use can be made of sunlight, soil nutrients and rainfall. The strategy exploits the complementarities and synergisms that result from the various combinations of crops, tree and animals in spatial and temporal arrangements[24].

Various strategies to restore agricultural diversity in time and space include crop rotations, cover crops, intercropping, crop/livestock mixtures, and so on, which exhibit the following ecological features:

1. Crop Rotations. Temporal diversity incorporated into cropping systems, providing crop nutrients and breaking the life cycles of several insect pests, diseases, and weed life cycles [18,20].

2. *Polycultures*. Complex cropping systems in which tow or more crop species are planted within sufficient spatial proximity to result in competition or complementation, thus enhancing yields[9,10].

3. *Agroforestry Systems*. An agricultural system where trees are grown together with annual crops and/or animals, resulting in enhanced complementary relations between components increasing multiple use of the agroecosystem.

4. *Cover Crops*. The use of pure or mixed stands of legumes or other annual plant species under fruit trees for the purpose of improving soil fertility, enhancing biological control of pests, and modifying the orchard microclimate.
5. Animal integration in agroecosystems aids in achieving high biomass output and optimal recycling .
All of the above diversified forms of agroecosystems share in common the following features[1,2]:
a. Maintain vegetative cover as an effective soil and water conserving measure, met through the use of no-till practices, mulch farming, and use of cover crops and other appropriate methods.
b. Provide a regular supply of organic matter through the addition of organic matter (manure, compost, and promotion of soil biotic activity).
c. Enhance nutrient recycling mechanisms through the use of livestock systems based on legumes, etc.
d. Promote pest regulation through enhanced activity of biological control agents achieved by introducing and/or conserving natural enemies and antagonists.

Research on diversified cropping systems underscores the great importance of diversity in an agricultural setting. Diversity is of value in agroecosystems for a variety of reasons: As diversity increases, so do opportunities for coexistence and beneficial interactions between species that can enhance agroecosystem sustainability.

Greater diversity often allows better resource-use efficiency in an agroecosystem. There is better system-level adaptation to habitat heterogeneity, leading to complementarity in crop species needs, diversification of niches, overlap of species niches, and partitioning of resources [22,23]. For example maize-pumpkin intercropping system has better productivity in both conventional and conservation farming system than sole crops[21] (Figure 1).

Ecosystems in which plant species are intermingled possess an associated resistance to herbivores as in diverse systems there is a greater abundance and diversity of natural enemies of pest insects keeping in check the populations of individual herbivore species.

A diverse crop assemblage can create a diversity of microclimates within the cropping system that can be occupied by a range of noncrop organisms - including beneficial predators, parasites, pollinators, soil fauna and antagonists - that are of importance for the entire system.

Diversity in the agricultural landscape can contribute to the conservation of biodiversity in surrounding natural ecosystems.

Diversity in the soil performs a variety of ecological services such as nutrient recycling and detoxification of noxious chemicals and regulation of plant growth.

Diversity reduces risk for farmers, especially in marginal areas with more unpredictable environmental conditions. If one crop does not do well, income from others can compensate.

Another practice is cover cropping or the growing of pure or mixed stands of legumes and cereals protect the soil against erosion; ameliorate soil structure; enhance soil fertility, and suppers pests including weeds, insects, and pathogens. Cover crops can improve soil structure and water penetration, prevent soil erosion, modify the microclimate and reduce weed competition. Besides these effects, cover crops can impact the dynamics of orchards and vineyards by enhancing soil biology and fertility and by increasing the biological control of insect pest populations.

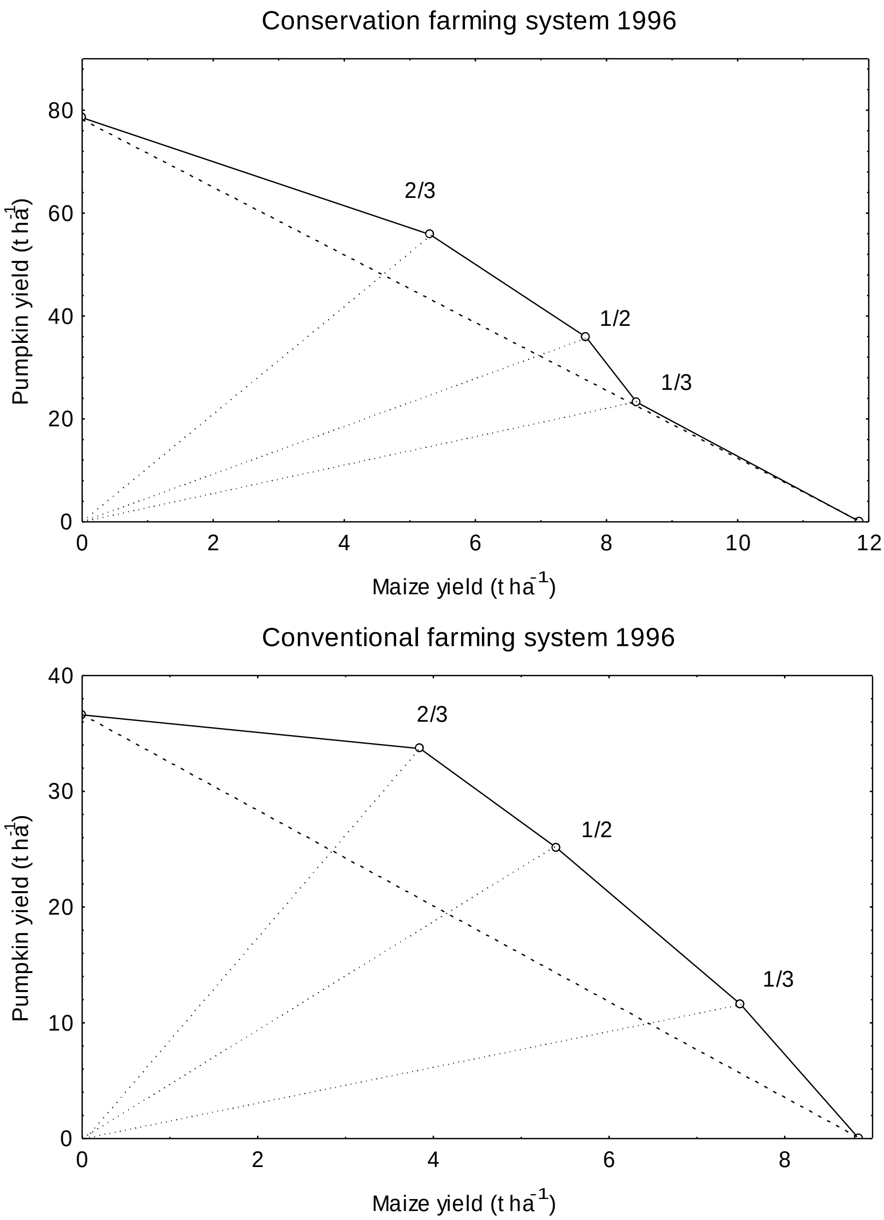

Figure 1. Bivariate diagrams of maize-pumpkin intercropped pumkin and maize (the dashed line joining the monoculture yield of the two components represents conditions where LER=1; the lines radiating from the origin indicates various proportions of component crops[(21)]).

Critics of such alternative production systems point to lower crop yields and in high-input conventional systems. Yet all too often it is precisely the emphasis on yield a measure of the performance of a single crop-that blinds analysts to broader measures of sustainability and to the greater per unit area productivity obtained in complex, integrated agroecological systems that feature many crop varieties together with animals and trees. There are also cases where even yields of single crops are higher in agroecological systems that have undergone the full conversion process.

CONCLUSION

Low-external input technologies implementation and adoption in food production is expected. All of this will be contribute to rational management based on existing resources on the farms. It will be contribution in safe food production and spreading of ecological consciousness. In that way of food production will be implemented the international standards in crop production and adjust ours with international regulations. Farming systems aimed at minimizing or eliminating the net-depletion element will also reduce many of the external costs of agriculture to society such as the cost of soil and other pollutants in lakes and rivers.

REFERENCES

1. Altieri, M. A. (1987): Agroecology: the scientific basis of alternative agriculture. Boulder: Westview Press.
2. Altieri, M.A. (1994): Biodiversity and pest management in agroecosystems. Hayworth Press, New York.
3. Birkas, M., Szalai T., Nyarai, F., Hollo S. (1995): Soil cultivation and crop production systems of sustainable farming. Bult. of the Univ. of Agric. Sci: 109-122.
4. Broćić, Z. (1994): Uticaj organskih i mineralnih djubriva i vremena obrade na promene fizičkih i hemijskih osobina zemljišta i prinos kukuruza. Doktorska disertacija, 102 pp Poljoprivredni fakultet, Zemun.
5. Budoi, Gh. & Ciontu, C. (1995): The rotation of crops, a basic component of sustainable agriculture. Lucrari Stiintifice Vol. 38, 136-140.
6. Coolman, R. M. & Hoyt, G. D. (1993): The effects of reduced tillage on the soil enviroment. Hort Tehnology. Vol. 3, No. 2, 143-146.
7. Coolman, R. M. & Hoyt, G. D. (1993): Increasing sustainability by intercropping. Hort Tehnology. Vol. 3. No. 3, 309-313.
8. Cvetković, R., Oljača Snežana, Kovačević, D., Momirović N. (2000): Potreba i značaj ekologizacije biljne proizvodnje. Zbornik radova, Eko-konferencija 2000: Zdravstveno bezbedna hrana. Knjiga II, Novi Sad, 63-68.
9. Francis, C. A (1986): Multiple cropping system, Macmillan Publishig Company, 383 pp, New York.
10. Francis, C. A (1989): Biological efficiencies in multiple-cropping systems, Advances in Agronomy, 42, 1-37.
11. Gliessman, S.R. (1998): Agroecology: ecological processes in sustainable agriculture. Ann Arbor Press, Michigan.
12. Govedarica, M., Milošević, N., Jarak, M., Ubavić, Radanović, M., Z. (1996): The effect of earthworm and green manure on the microbiological activity in wheat. Zemljište i biljka. Vol. 45, No. 2, 121-127.
13. Kovačević, D., Oljača Snežana, Oljača, M., Broćić, Z., Ružičić, L.,Vesković, M., Jovanović, Ž. (1997): Savremeni sistemi zemljoradnje: korišćenje i mogućnosti za očuvanje zemljišta u konceptu održive poljoprivrede, Zbornik radova IX Kongresa JDPZ, 101-113, Novi Sad.
14. Kovačević, D., Oljača Snežana, Radošević, Ž., Birkás Márta, Schmidt, R. (1999): Konvencionalni i konzervacijski sistemi obrade zemljišta u važnijim ratarskim usevima. Poljoprivredna tehnika, Vol. 23, No.1-2, 83-93.

15. Kovačević, D., Momirović, N., Oljača Snežana, Denčić, S., Kobiljski B. (1999): Effect of tillage systems on weed control and yield of winter wheat in low-input technology. Proceedings of 11th EWRS Symposium, Basel, 107.

16. Kovačević, D. Momirović, N., Denčić, S., Oljača Snežana**,** Kobiljski, B. (2000): High vs. low-input winter wheat cultivars response under different farming and weed management systems. 6th International Wheat Conference, Proceedings of abstracts, Budapest, 251.

17. Lynam, J.K., Sanders, J.H., Mason, S.C. (1986): Economics and risk in multiple cropping, In Multiple cropping system, Macmillan Publishig Company, 285-292, New York,.

18. Momirović, N., Cvetković, R., Radošević, Ž., Oljača Snežana (1998): Duble cropping-a field production method toward agriculture intensification and agroecosystem protection, Ekologia, Vol. 33, 55-62.

19. Leibhardt, C. W., Andrews, W. R., Culik, N. M., Harwood, R. R., Janke, R. R., Radke, K. J, Reiger-Schwartz, S. L. (1989): Crop production during from conventional to low-input methods. Agronomy Journal, Vol. 81, 150-159.

20. Marsh, S. J. (1993): Strategies for sustainable agriculture. Conference proceedings, Marton Vasar, 11-21.

21. Momirović, N., Oljača Snežana, Vasić, G., Kovačević, D., Radošević, Ž. (1998): Effects of intercropping pumpkins (Cucurbita maxima Duch.) and maize (Zea mays L.) under different farming systems, Proceedings of 2nd Balkan Symposium on Field Crops, Novi Sad. 251-255..

22. Oljača Snežana, Cvetković, C., Kovačević, D., Vasić, G., Momirović, N. (2000): Effect of plant arrangement pattern and irrigation on efficiency of maize (*Zea mays*) and bean (*Phaseolus vulgaris*) intercropping system. Journal of Agricultural Science, Cambridge, Vol. 135, 261-270.

23. Oljača Snežana, Cvetković, R., Kovačević, D., Milošev, D. (2000): Diverzifikacija agroekosistema kao način zaštite i očuvanja neobnovljivih prirodnih resursa. Zbornik radova, Eko-konferencija 2000: Zdravstveno bezbedna hrana. Knjiga II, Novi Sad, 81-86.

24. Vandermeer, J.H. (1989): The Ecology of Intercropping. Cambridge University Press, 231 pp, Cambridge,