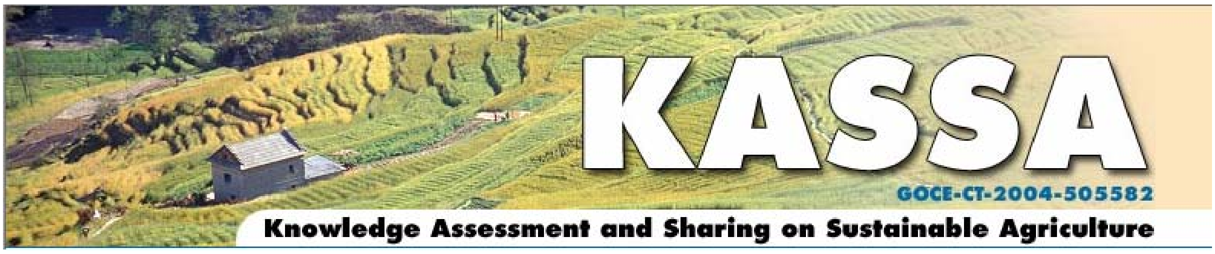

Prospects for sustainable agriculture in the Latin American platform of KASSA

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Context

LA participants agreed on the need to adapt the workpackage guidelines for the drafting of the report to the specific context of the LAM platform, where CA is already a farmers practice. In the case of LAM platform the issue is not only CA dissemination, but also: what are the main issues arisen from the adoption.

LAM is recognized as a sort of “model” or “reference” regarding the adoption of CA by both small and large scale farmers. In addition, in many areas such as soil science, weed management and agronomy, a lot of scientific information is available.

However, nothing is static and this is particularly true in agriculture. Once farmers move from one system to another, new dynamics are created and new questions arise. These are the new knowledge gaps that should be tackled.

As regards the issue of dissemination in LAM, in some situations CA is still not being practiced, due to some constraints of different nature; in other situations – such as the case of small-scale agriculture in the subtropical areas of Brazil –CA is being practiced partially, as a result of farmer’s adaptation of CA concepts to their objectives, priorities, and to economic, environment and agro-ecological conditions. These adaptations to more or less sustainability regarding the CA model need to be assessed.

Therefore, participants of the LAM platform decided to adapt the content of the report R3.4 (according to the DoW and to the decisions taken by the CMU M3), focusing on three main questions:

a) *Which are the new knowledge gaps arisen from the transition from conventional agriculture to CA?*
b) *How farmers have been practicing CA?*
    1. *What are the impacts of their practices?*
    2. *Can these practices be improved and how?*

c) *Why in some situations, the adoption of CA is still constrained? And, how dissemination could be fostered in these cases?*

1 Methodology

Analysis was made separately for each country and within the country, according to the different agro-ecological regions and different socio-economic categories of farmers. Since the beginning of KASSA, the participants of the LAM platform agreed on the need to make a separate analysis for small-scale agriculture and large-scale agriculture; although CA concept is the same, the complexity of the farming systems, the access to resources and the suitability of the available technologies differ from one category to another.

We also made a separate discussion on what was called “dissemination” and “improvement”. The first case is related to the question c) and the second relates to question b.2).

In order to guide the discussion about dissemination, it was firstly necessary to have some figures on the adoption of CA by the different socio-economic categories of farmers, as well as for the different agro-ecological regions in each country. Despite the availability of some official statistics, these are more general. Participants came up with the data presented in table 3, which was based on their experience. It can be seen only as a tool to guide the discussions.

Finally, the group discussions followed a dynamics that allowed the identification of the main constraints and their causes, followed by the identification of suitable technologies and approaches to the platform conditions and suggestion for the dissemination and improvement of CA technologies. This requires actions of different nature, such as policy, research, extension and others which are described in the tables 2 to 7.

2 Socioeconomic features and policy opportunities regarding the dissemination and improvement of Conservation Agriculture

The socioeconomic environment in Latin America, if not constraining to agriculture, is not really favorable. Most of the countries live under the specter of past high inflation rates and huge public debt. In order to deal with the economic situation local governments undertake the usual orthodox policy of high interest rates to keep inflation low and attract foreign investments. In addition, since some of the biggest Latin American countries, as Argentina and Brazil for example, are important commodity exporters, agriculture is a useful instrument for their economic policies as a foreign currency provider.

So, agriculture is penalized indirectly through the exchange rate, which is down driven through relatively huge inflows of foreign currency attracted by high interest rates as in Brazil; or directly through high export taxes, as in Argentina; or both. Also, the need to obtain high surpluses to serve foreign and domestic debt, as well as other purposes considered of higher priority, leave not enough money for agricultural credit on which both small and large scale farmers are highly dependent.

In such context, where agriculture is subject to general economic goals, one would not expect special policies promoting conservation agriculture. And there are not any indeed. Despite the existence of environmental legislation (Brazil's is said to be one of the best legislations) it was written basically to be enforced through punishment and not to further environmental consciousness through the sustainable use of natural resources, especially water and soil.

Few exceptions are the recent State government programmes in the subtropical region of Brazil, where government programmes have been promoting CA through providing funds for research, extension and credit (e.g. machinery) oriented to CA.

3 Constraints for dissemination of CA with a systemic concept and proposals

Table 1 presents some estimated figures of CA adoption in Argentina, Bolivia and Brazil, according to the main agro-ecological regions and socio-economic categories of farmers. This table was built based only on participants experience only for the purpose of comparing the situation within the countries.

Table 1 – Estimates of CA adoption rates (% of farmers) in Latin American countries according to the main agro-ecological regions and socio-economic categories of farmers.

		Argentina	Bolivia	Brazil
Tropical	Small-scale	-	40	5
	Large-scale	-	80	40
Subtropical	Small-scale	0	-	50
	Large-scale	55	-	75-80
Temperate/Central humid	Large-scale	70	-	-
Temperate/Sub humid	Large-scale	50	-	-

Tables 2, 3 and 4 present the main constraints to dissemination, their causes, distribution level of importance and proposals for Argentina, Brazil and Bolivia, respectively. These were grouped into 5 main categories: socioeconomic, agronomic, agro-ecological, institutional and cognitive aspects.

3.1 Socioeconomic aspects

- **Competitive use of residues due to the use of fodder for livestock**. Although being present in both categories of farmers, this constraint can be stronger for small-scale due to the lowest land availability. Even when farmers are aware of the benefits of leaving biomass for soil improvement, they may have short-term needs (e.g. feeding the cattle in Brazil, Bolivia and Argentina; **use as shelter and selling of crop residues** in Bolivia) which is a priority for them. Specifically in the case of Bolivian farmers (small-scale/subtropical) the traditional land use system is a strong constraint: after harvesting the cereals, every farmer has the right to bring his cattle to graze the crop residues. **Technical solutions** would consider a) the increase of biomass production trough the use multipurpose cover crops with higher biomass production; b) rotational grazing and c) the provision of alternatives sources such as fodder banks (e.g. Napier grasses), silage and others. These alternatives would be feasible when the land owner has the control of the land all over the year, which would be unfeasible for the Bolivian small farmers. In this case, firstly there is a need of changes in the traditional land use systems.

- **Offsite threshing**: this constraint is specific to small scale farmers from the Bolivian subtropics, who **have very small fields (around 1 ha) located in hilly landscapes and stony in some situations.** These conditions, combined to the **lack of capital** for the use of combines oblige farmers to harvest manually the crop and to thresh it outside the field**. The communal use of harvesting equipment** would be a solution, however feasible only in areas suitable for mechanization.

- **Lack of capital**: the transition from conventional agriculture to CA requires investment in equipment and external inputs, which may restrict the adoption by small-scale farmers, who have already low capacity of investment due to **the low profitability of production and restricted access to credit**. In the poorest areas (e.g. in the subtropical regions of Bolivia) agriculture is subsistence-oriented without surplus production that would allow to make investments for improvement of soils and crop yields. Some successful examples of programmes oriented to small-scale farmers in Brazil could be a reference for other countries. These programmes included the **provision of credit at low interest rates and oriented to farmers groups.**

- **Lack of conviction**: There is may be no perception on the importance of CA, mainly **when farmers have short-term needs** (e.g. need of short-term income), that are ranked in the top of their priorities. Also**, tradition and cultural** aspects can limit the dissemination, although cultural issues are less documented. Farmers may also see that CA is not feasible because it may lead **to soil compaction** which may happen in the situations where soils have high clay or silt content. In situations where benefits of CA are clear, improved communication strategy is required, trough **the strengthening of farmer-to-farmer communication.** Specifically for the case of Bolivia, **strengthening of the extension system** is necessary.

- **Policies**: In general, **there are no specific policies for CA** at a medium to long term. Most commonly, the agricultural sector has been considered as an anchor for the economy and for the development of other economic sectors rather than establishing medium and long term policies that promote a sustainable growth of the sector. In Argentina, high taxation (export taxes are as high as 20% or more for most of the agricultural products) erodes farmers´ profits and limit them to build up enough capital to invest in CA. Also credits are regularly of low availability and interest rates are high. A result of this reality, regularly the agricultural sector more than having official incentives had to deal with an "extra cost" derived from high taxation policies and had to learn how to deal with it in order to remain competitive.

3.2 Agro-ecological aspects

- High percentage of small-scale farmers, in both tropical and subtropical regions, is located on **hilly areas and stony soils**. Despite the availability of human and animal-drawn machinery for small-scale farmers, drudgery is still a constraint, such for instance, to carry knapsack sprayers or to use hand-jab planters in clay-textured soils. There is still a need **to develop equipment adapted to these conditions**

- In Argentina, except for the temperate central humid area where the rainfall limitations are lower in intensity and frequency and regularly the water availability for crops under rainfed agriculture is good, for the rest of the country (temperate sub-humid and subtropical region) plant growing conditions are more limited. The reason comes from a combination between **the rainfall pattern (regularly monzonic pattern) and the water balance (frequently deficient**). **The production of biomass (and hence crop development and final yield) is frequently limited or restricted** to some extent making the adoption process more difficult than in the central temperate humid area. In the tropical areas of LAM, the uneven pattern of **rainfall distribution is a constraint that limits the**

planning of production models. The high temperature and soil moisture speed up the rate of decomposition of plant residues remaining on the soil surface, not allowing formation of a mulch layer

3.3 Farmers´perceptions and cultural aspects

- Some farmers from both tropical and subtropical regions, independent of farm scale, are **not convinced of the benefit of adopting CA**. This lack of conviction may be of different origins, as **tradition, culture, religion (such as Mennonite farmers in Bolivia) or because they have other short-term priorities** (mainly small-scale farmers).

- The dissemination of CA acreage is restricted by farmer's perception that the continued use of the system would **compact the soil.** This is observed by farmers of both production scales in both regions. However, small-scale farmers are more reticent than large-scale farmers. **This farmer's perception is more evident under soil moisture stress associated to high clay and low organic matter content or in soils with high silt content. There is a need to evaluate to what extent farmers´perception corresponds to real problems of soil compaction.**

3.4 Agronomic aspects

- Due to some inherent management practices related to planting, pests control and harvest, **some crops are not cultivated under CA**:
    - In Brazil, despite of the available technologies for the cultivation of **cotton** (large-scale farmers at tropical region) under CA principles, residues are buried (plowed) in order to prevent the incidence of the pest *Anthonomus grandis.*
    - In Brazil**,** **tobacco** is cultivated by small-scale farmers at subtropical region. Despite the efforts of tobacco companies in the promotion of the cultivation of tobacco under the CA principles, this crop is being cultivated under conventional system. Although lacking scientific data, evidences from farmer's experiences indicate that the main reasons for the non adaptation of tobacco to CA are: a) susceptibility of the crop to high soil moisture; higher incidence of slugs in CA mainly during wet periods and c) lack of broadleaves herbicides. Thus, **research on IPM methods** is required.
    - Although the availability of technologies for **potatoes, groundnuts and cassava,** when these crops are harvested, great amounts of soil are disturbed. **Development of harvesting equipment** with lower soil disturbance is required

- In order to promote a good soil covering, one of the major constraints is related to the **insufficient amount of straw and its high decomposition rate under tropical and some specific situations in subtropical conditions**. Among the factors that cause this problem are: a) **monocropping and/or inappropriate rotational techniques** (mostly for large scale farms for both tropical and subtropical regions; b) **lack of adapted cover crops species and low biomass yield,** mainly for the tropical region where the number of crop species adapted to abiotic stress (such as drought) is small. **A great demand for cover crop species improvement program is thus required**

3.5 Institutional aspects

- In the past most of the research work related to CA in Argentina has been done following a non-systemic, non-interdisciplinary approach. The value of interaction among factors within the system was almost systematically not considered. This fact has generated in some cases **conflicting messages** like research conclusions suggesting ploughing or even burning straw to control some plant diseases without any consideration of their value as basic inputs for the achievement of the several benefits that CA system is offering when it is well understood and correctly implemented. Adoption process was mostly driven by leader farmers. At that time, **neither universities nor the official research and extension structures were very supportive of the transformation of the farming system toward CA (**No Till). As a result of this, some unclear non-consistent messages (mostly originated by the academic and research sector) were to some extent limiting a possible faster and wider adoption of the CA across the country. Also the good results (as well as the managerial, agronomic and technical issues to be properly solved for a successful adoption) obtained by early adopters has not always reached the potential adopters in a clear manner. Nowadays the situation has improved significantly however some limitations still exist and call for **the promotion of interdisciplinary research approaches**.
- Given the great diversity of environmental and edaphic conditions found within LAM platform, there are many **knowledge gaps on interdisciplinary research with systemic approach for the development of production systems compatible with the CA practices, mainly for small-scale farmers at the tropical region**. In addition, sometimes the research institutions and rural extension services do not have the consensus about the benefits of CA, reflecting their adoption level.
- In Bolivia, mainly in the subtropical region, there is a lack of research information both for farmers and technicians. Rural extension is very weak, technicians are not convinced by the benefits of CA and technical messages for farmers are not clear. In the tropical area, there is also a lack of scientific information mainly for small-scale farmers. Moreover**, in some regions where local languages predominates among farmers and the high unliterary also hinders the farmers' access to external information.**

Table 2 – Constrains to the dissemination of CA in Argentina

Constraint	Causes	Temperate		Subtropical
		Central humid area	Sub-humid area	
Competitive use of residues	Use as fodder for livestock		xxx	xxx
Lack of capital	Low profitability due to high taxes (production) and low availability of credit at compatible interest rates	x	xxx (mainly machinery)	xxx (mainly machinery)
Lack of conviction (benefits are not clearly seen)	Farmers' perception (tradition, culture, priorities)	x	xxx	xxx
	Ineffective communication of results	x	xx	xx
Climate			x (rainfall pattern)	x (rainfall pattern)
Lack of governmental incentives	Lack of a proper agricultural policy	x	x	x
Insufficient amount of straw (low production and high decomposition rate)	Monocropping/inappropriate rotational pattern	x	xxx	xxx
	Rainfall (amount and distribution)		xx	xx
	High temperatures and moisture		x	xx
Insufficient knowledge	Lack of interdisciplinary research with a systemic approach (mainly medium to long term)	x	xx	xx
	Conflicting messages	x	x	x
Lack of alternatives for crop rotation	Low profitability (prices, production costs, freight and handling)	x	x	x
Lack of governmental incentives	Lack of a proper agricultural policy	x	x	x

Table 3 – Constraints to dissemination of CA in Bolivia

Constraint	Causes	Tropical		Subtropical
		Small-scale	Large-scale	Small-scale
		50	80	0
Competitive use of residues	Use as fodder for livestock	x		xxx (communal grazing)
	Source of income	x		xx
	Use as roofing			xx
Lack of capital	Low profitability and restricted access to credit	xx	x	xxx
Offsite trashing	Small scale production, hilly landscape and stony soils constrains the use of combines			xxx
Insufficient knowledge	Lack of interdisciplinary research with a systemic approach	xx	x	xxx
Lack of convincement (benefits were not clearly seen)	Farmers' perception (tradition, culture, priorities)	xx	x	xxx
	Not effective communication of results	xx (language constraints)	x	xxx (language constraints)
Lack of economic alternatives for crop rotation	Low profitability (low prices, high production costs)	xx	x	xxx
	Low yields	xx	xx	xxx
Religious aspects		x (menonite)		

Table 4 – Constraints to dissemination of CA in Brazil

Constraint	Causes	Tropical		Subtropical	
		Small-scale	Large-scale	Small-scale	Large-scale
		5	40	50	75-80
Competitive use of residues	Use as fodder for livestock	xx	x	xx	x
Lack of capital	Low profitability due to small production scale and low availability of credit	xxx		xx	
Lack of convincement (benefits were not clearly seen)	Farmers' perception (tradition, culture, priorities)	xx	x	x	
	Not effective communication of results	xx		x	
Soil compaction	Farmer's perception	xx	x	xx	x
Landscape		x		x	
Stony soils		x		x	
Some crops are not cultivated under CA	Soil characteristics (tobacco), legal aspects (cotton), planting and harvesting equipment (some horticultural crops) and insufficient adaptive research		xxx	xxx	
Lack of governmental incentives	Lack of a proper agricultural policy	x	x	x	x

3.6 Constraints for improvement of CA

Tables 5, 6 and 7 indicates the main factors that hinder the practice of CA according to its principles, or and "integral adoption" of CA.

- **Lack of crop rotations**: This was considered by participants of the LAM platform as one of the most important issues, because it is linked to many other constraints for the improvement of CA practices. Crop rotations are the core of sustainable CA systems and are associated to biomass production and are part of strategies of integrated weed and pest management.

  The adoption of crop rotation is constrained both by agro-ecological and socioeconomic factors. For instance, in the Bolivian tropics in all production scales, farmers have been using direct seeding without crop rotation (e.g. soybeans-fallow; soybeans-sunflower; soybeans-sorghum) or rotation only during the winter), which have been the most adapted species to the conditions of high temperature and low rainfall during some periods of the year. However, in the subtropical areas of the LAM the climate allows the cultivation of many crops, many research results has shown the benefits of crop rotations and farmers are aware of this. In this case, **the practice of crop rotation is constrained because these alternatives are not economically viable under an economic context where prices are market-driven and there is virtually no policy that favors the use of crop rotations.** In Argentina, due to the economic

restrictions derived among other reasons from a high taxation (exportation taxes) and related low price obtained by the farmers as well as high cost in other crops, gives birth to a **lack of equally profitable alternatives seriously restrict the implementation of a proper agronomic rotational strategy** (large enough in number of species and in time). Under this scenario, and while looking for a profitable enough crop alternatives, mono-cropping situation is heavily promoted. Soybean growth as the predominant crop year after year constitutes the emblematic Argentinean case for this issue, but this situation has also been common in Brazil and Bolivia.
Policies providing incentives (e.g. premium prices) to CA in order to promote the diversification of crops under CA should be proposed not withstanding the prevailing market economy.

- **Insufficient amount of straw**: This is attributed to some factors such as **monocropping/inappropriate rotational patterns** (already discussed above) but also to **the low biomass production and high decomposition rates** in most of the tropical areas and parts of the subtropical areas. Low biomass production could be overcame with breeding, selection and introduction of adapted genotypes and biotechnology development. However, it must be highlighted that, while biotechnology and more specifically, genetic modified crops were seen as one alternative for obtaining plants adapted to dry climatic environments both by Argentina and Bolivian participants, Brazilian participants made an option of firstly assess the environmental and economic impacts of these technologies.

- **Soil compaction:** The improvement of CA, in both tropical and subtropical regions, is limited by soils with high clay or silt content, as well as, low level of organic matter that can induce soil compaction when managed under inappropriate production models. Although high clay content soils occur on both regions, the problem is more frequently observed on large-scale farms. Low content organic matter soils are more frequently observed under tropical conditions. In this case, **research introducing plant species with high plant biomass production is required.** It is also observed that in some cases, **soil compaction may be rather a result of a farmers´ perception, which still remains an issue to be further studied.**

- **Pest management**: The practice of CA generates a new dynamics, with the selection of some weeds, insects and diseases, and reduction of others. Crop rotations are the pillar of any IPM/IWM program; therefore, if crop rotations are not used in CA, the reliance on chemicals is higher, resulting in higher costs and negative environmental consequences. Monocropping and inappropriate rotational patterns must be readapted to higher soil moisture conditions, where the straw accumulation can be a shelter for many plant plagues and diseases. **More research on both tropical and subtropical regions is required, aiming to identify cash and forage crop species adapted for several rotational systems and to develop alternatives to chemical control for CA, starting by basic studies aiming at understanding the dynamics of pests and weeds generated by the introduction of CA.**

Table 5 – Constraints to the improvement of CA in Argentina

Constraint	Causes	Temperate		Subtropical
		Central humid area	Subhumid area	
Insufficient amount of straw (low production and high decomposition rate)	Monocropping/inappropriate rotational pattern	x	xxx	xxx
	Rainfall (amount and distribution)		xx	xx
	High temperatures and moisture		x	xx
Insufficient knowledge	Lack of interdisciplinary research with a systemic approach (mainly medium to long term)	x	xx	xx
	Conflicting messages	x	x	x
Lack of alternatives for crop rotation	Low profitability (prices, production costs, freight and handling)	x	x	x
Lack of governmental incentives	Lack of a proper agricultural policy	x	x	x

Table 6 – Constraints to the improvement of CA in Bolivia

Constraint	Causes	Tropical		Subtropical
		Small-scale	Large-scale	Small-scale
Insufficient amount of straw (low production and high decomposition rate)	Monocropping/inappropriate rotational pattern	xx	xx	xxx (e.g. potatoes)
	Rainfall (amount and distribution)	xx	xx	xxx
	High temperatures and moisture	xxx	xxx	x
Insufficient knowledge	Lack of interdisciplinary research with a systemic approach	xx	xx	xxx
Lack of alternatives for crop rotation	Low profitability (low prices, high production costs)	xx	x	xxx
	Low yields	xx	xx	xxx

Table 7 – Constraints to the improvement of CA in Brazil

Constraint	Causes	Tropical		Subtropical	
		Small-scale	Large-scale	Small-scale	Large-scale
Insufficient amount of straw (low production and high decomposition rate)	Monocropping/inappropriate rotational pattern	x	xx	x	xx
	Rainfall (amount and distribution)	xxx	xxx	x	x
	Lack of adapted cover crop species	xxx	xxx	x	x
	High temperatures and moisture	xxx	xxx	x	x
Insufficient knowledge (knowledge gaps)	Lack of interdisciplinary research with a systemic approach	xxx	xx	xx	x
	Conflicting messages	x	x	x	x
Lack of economically viable alternatives for crop rotation	Low profitability (prices, production costs, freight and handling)	x	x	x	x
Lack of governmental incentives	Lack of a proper agricultural policy	x	x	x	x
Soil compaction	High clay content	x	xx	x	xx
	High silt content	x	x		
	Low organic matter content	xx	xx	x	x
	Overgrazing	xxx	xx	xx	x
	Low biomass production	xx	xx		
Pests management	IPM not fully adopted, monocropping/inappropriate rotational pattern, higher soil moisture, shelter...	xx	xx	xx	xx
Equipment	Low reliability of planting and spraying equipment	x		x	
	Low technical quality of sprayers	xx		xx	

4 The best geographical situations and biophysical conditions where these technologies and approaches in support of CA are likely to succeed quickly within the platform.

4.1 Climate

No-till system in more likely to succeed in regions of subtropical moist or temperate climate in which the rainfall pattern is evenly distributed during the year. These climate characteristics assure organic material production all over the year, promoting permanent soil protection. Under less favorable climate conditions the success of no-till system depends on the availability of plant species and/or cultivars that fit into regional production models.

4.2 Soil

No-till system is better adapted to regions in which landscape is flat to slightly rolling in order to facilitate machinery operations to plant, to spray, and to harvest. In less favorable landscape conditions complementary soil conservation practices to control runoff as terracing, grassed water ways etc., can be necessary and interfering with the free machinery traffic.

As no-till system requires reduction in soil disturbance plant roots present better development under medium textured soils as clay silt loams. As the clay content in the soil increases the development of rooting systems of different crops are more dependent on the soil structure than on soil texture. Soils with clay content relation higher than one between B horizon and A horizon can present restriction for root growing and water infiltration rate when not tilled. Soil compacted layers present the same level of restriction, reducing the soil permeability to air, water, and root. These aspects can be limiting factors for the no-till system adoption. Similarly, soils with presence of expansive clays impose restriction to the adoption of no-till system, mainly due to the small period of ideal moisture content to plant any crop. Rocks on the soil surface as well as shallow soils impose restrictions for most of equipment operations in one farm.

In order to assure success of no-till system adoption soil fertility status can be a problem. One of the main constraints of chemical limitations is soil salinity. The soil acidity is indicated to be correct before adopting no-till system.

4.3 Pests

No-till system is better suited in areas of low weed infestation; otherwise the production cost would be higher than the conventional tillage system. Areas with absence of herbicide-resistant weeds and absence of difficult to control weeds should be first put under no-till system. These aspects would help the process of learning by doing that the farmer has to overcome.

Other strategies indicated to be adopted by farmers entering the system is the availability of plants tolerant to insects and diseases, mainly due the dynamics in changing the behavior of insects and diseases.

5 Socioeconomic and environmental expected impacts

5.1 Socioeconomic impacts

- Reduction in drudgery, in fuel/lubricants and in mechanized operations
- Wide-scale adoption by small-scale farmers in LA platform made possible to assess that the transition to CA resulted in better livelihoods

5.2 Environmental

- Increase on soil organic matter
- Increase in N contents in the upper soil layers
- Higher probability of downward N leaching under CA in humid regions
- Higher efficiency of N fertilizers is reported by the LAM, European and Mediterranean platforms
- Erosion reduction through topsoil cover crops/residues.
- Increase of the enzymatic activity as a result of CA

- LAM reports an increase of the microbial biomass and C in the topsoil and an increase of SOM and nematodes.

6 Knowledge gaps to be filled, research topics and approaches for achievement

6.1 Impact assessment of the use of external inputs in CA on soil and water quality and on biodiversity

High soil quality is a requirement for the conservation of water resources, in addition to being the basis for sustainable agricultural production and to improve ecosystem functions. Ideally, by keeping the soil covered with a straw layer and sowing directly with minimal soil disturbance and using complementary conservation practices such as terracing systems, CA reduces soil erosion and the runoff of water, soil sediments and organic matter to rivers and small streams. However it has been observed that the partial adoption of CA practices is some countries has resulted in an increase in the use of external inputs such as pesticides. Further research is necessary to better quantify these aspects.

The is a need to define, for every agro-ecological region, a minimum data set of soil and water parameters that best indicate their improvement or degradation. These studies must take into account the diversity of CA systems found all over the region.

6.2 Definition of soil quality indicators for different agro-ecosystems

Practical assessment of soil quality requires a consideration of the physical, chemical and biological functions of the soil. The identification of early warning indicators of ecosystem stress is needed to provide strategies and approaches for land resource managers and policymakers to promote long-term agricultural sustainability. Many evidences show that the microbiological indicators (soil microbial biomass and diversity and soil enzymes activities) are able to detect early changes in soil quality. Since there is a variety of methods to assess the microbiological status of a soil, studies must be conducted to define what methods should be included in a data set of microbial indicators of soil quality in concert with soil chemical and physical measurements.

Considering the continental dimensions of the LAM platform, it is probable that a soil quality data set will vary from region to region and even among the different management systems in one same region. Another challenge consists in defining the critical values for each of the parameters of these data set, and the most appropriate reference areas (native/ undisturbed vegetation) that will act as control or base line. Efforts in terms of the definition of a soil quality index are necessary to identify problem areas and to monitor changes in sustainability and environmental quality as related to agricultural management. The idea is that in the future, assessments of the soil quality status of a given area could be made in a routine basis by using proper indicators that are at the same effective, simple, cheap and relatively rapid, allowing the farmer to evaluate the impacts of local management systems.

6.3 Dynamics of soil organic matter in agro-ecosystems

The clearing and cultivation of undisturbed native areas is accompanied by a decline in soil organic matter (SOM). In the humid tropical regions, SOM decomposition may be intense due to high mean annual temperature and precipitation, especially under intensive or annual soil tillage. Conventional tillage practices cause a disruption in soil aggregates and place crop residues in intimate contact with soil, leading to a more rapid decomposition than surface placement with no tillage. CA practices, especially no-till, result in the accumulation of organic matter in the first few centimeters of the soil profile. On the other hand, carbon levels at lower depths are similar in both systems, or slightly higher under plow tillage. The stratification of SOM observed under no tillage systems associated with increased levels of soil moisture and smaller variations in temperature, due to soil cover, reflects directly upon the soil microbial community, which has its total microbial biomass and activity more concentrated in the first centimeters of the soil profile as well. For this reason the biological functioning of soils under no tillage systems is completely different of that found in soils under conventional tillage, which affects the organic matter dynamics in the whole system. Diverse crop rotations can change soil habitat by affecting nutrient status, depth of rooting, amount and quality of residue, aggregation/microbial habitat, and microbial activity. For these reasons, the consequences of the partial adoption of CA practices with the large predominance soybean monocropping on the different size fractions of soil organic matter with different turnover times also need to be addressed.

Losses and gains of soil organic carbon are not well defined for principal soils in LAM and more studies are necessary to fill in these gaps. The studies on soil organic matter dynamics (quality, decomposition and accumulation) should be carried out under different management systems including soybean monocropping, and ley farming systems. The changes in SOM and their implications for microbial activity, nutrient cycling, soil structure, aggregates stability and water storage in the humid tropics also need to be determined.

6.4 Quantification of the potential of CA for carbon sequestration

Investigations of the soil organic carbon (SOC) dynamics of tropical and subtropical soils can provide valuable information on how to manage such soils to increase stocks and promote C sequestration. Compared to conventional tillage, no-tillage increases the C stocks. Most research on tillage impacts on soils of Latin America is not readily available on literature. Some studies have reported similar mean rates of C sequestration for Brazilian and North and American soils, for instance. However assessments of changes in SOC stocks for different LAM eco-regions or different non-intensive systems are inconclusive due to high variability and small number of observations. The adoption of CA in large areas such as the Brazilian Cerrados (occupying 207 million hectares) and its impact on C sequestration needs more investigation.

Research on the potential of CA for carbon sequestration needs to include data on SOC concentration and bulk density for different layers, but at least to the depth of disturbance (typically 20-40 cm), so that SOC stock and dynamics can be assessed. A larger data base of undisturbed and cultivated soils needs to be compiled to enable better assessment and modeling of SOC with land use change for major LAM eco-regions and soil types (specially regarding clay content and mineralogy).

6.5 *Development of cash and cover crops more tolerant to abiotic stress and compatible to different farming systems*

By building up organic matter both directly through decomposition of root and shoot residues, and indirectly through stimulation of microbial activity in their rhizospheres legume and non-legume cover crops have show some potential for improving soil structure. In temperate regions these effects include: reductions in bulk density and soil resistance, increases in water retention, infiltration properties and in the stability and amount of macro-aggregates. In addition, while a legume winter cover crop can be a significant source of N for the summer crop, non-legume cover crops can sequester residual nitrate and prevent leaching to ground water. Although crop rotation is one of the most important aspects related to the no-tillage management systems, due to climatic conditions and sometimes economic reasons, few farmers are able to use cover crops for their properties. In the tropical region the most limiting factors are the planting date, which generally occurs after the harvest of the cash crop, and the reduced amount of rainfall during the winter season.

There is a need to select drought tolerant cover crop species adapted to tropical conditions that can de planted after harvesting the cash crops. These species must have a fast initial growth, promote a good soil covering and be able to improve soil chemical, physical and biological properties.

6.6 Dynamics of soil nutrients in agro-ecosystems and technology development for the increase of efficiency of liming and fertilization;

Research developed under CA, in LAM Platform, has shown that the rate, placement and timing of fertilization and soil acidity correction by limestone and consequently nutrients dynamics are altered by adoption of no-till system. Some nutrients concentrate on the surface layers, increasing the risk of loss by runoff, while others are lost by leaching. In addition, by eliminating soil tillage the availability of nutrients to plants is increased. So, the recommendation of fertilizer and limestone for different crops used in various production models that were developed for conventional tillage, require adjustment for rate, placement, and timing. These aspects aim to promote reduction in production systems cost and to prevent environmental impact.

This type of study has to be carried out under systems' approach considering the different agro ecological and different socio-economic conditions. These aspects have to be assessed through field studies and on-farm validation and demonstration.

6.7 Studies of genesis, diagnosis, and mitigation of soil compaction in CA areas

Under no-till system in various agro ecological conditions, the farmer has the perception and different soil studies have shown development of compacted layer. This compacted layer, characterized by increased soil bulk density and soil resistance to penetration, and reduction of macro pores and total porosity, restricts water fluxes, air diffusion, and plant root development. Chisel plowing has not been a solution for to this problem. The use of crops in the production models that don't add organic material higher than the decomposition rate may be the main cause of this problem under no tillage. So, studies of the causes, diagnosis, and mitigation of soil compaction in CA areas, require technology development. Solution of this aspect aims to avoid climate risks and harvesting losses.

This type of study has to be carried out under systems' approach considering the different agro-ecological conditions and different socio-economic and biophysical features, considering mainly the plant species with potential to add more organic material to the system.

6.8 Technology development for runoff management in CA

Under no-till system farmers and technician have perception that the soil surface coverage is sufficient to control soil erosion. This perception has induced farmers to plant without paying attention to landscape and removing all terraces from the field. Terracing systems developed for conventional tillage are too dense to be maintained under no tillage. In fact conventional tillage terracing imposes far more difficulties for any farm operation than really help to control erosion, mainly due to the highly rolling landscape. These problems associated to the concentration of nutrients on soil surface and intensive rainfall events have promoted losses of soil, water, nutrients, and inputs on site specific points of farmers' fields.

This problem requires field studies, considering the different agro-ecological conditions, oriented to the development of strategies to control runoff in specific points of the field under no-till system.

6.9 Technology development for precision agriculture

CA considers that farming systems have to focus on economic, social, and environmental aspects, leading to the rational use of farming inputs.

These studies must contemplate different agro ecological conditions and different socio-economic and biophysical features, to develop technologies to efficiently use farming inputs so that to reduce production cost and avoid negative impacts to the environment.

6.10 Study (adaptation/breeding) of species aiming at cropping systems' diversification for different agro ecological conditions

Crop rotation is the key factor for the success of no-till system. Thus development of production models composed by different plant species has to be focused on. Plant breeding oriented to modify plant cycle and adjust seeding time, as well as to develop species to promote plenty organic material is an important tool to be used. The results of this research should be offered to the farmers a wider plant diversity aiming to plan production models with the least time among harvesting and planting the next crop.

These studies have to cover different agro ecological conditions and different socio-economic and biophysical features, in order to offer different plant materials to be fit in production models.

6.11 Analysis of the sustainability of farmers' CA practices in relation to the CA "model".

LAM is recognized as the region with the highest CA adoption rates, both by small-and large-scale farmers. The main components comprised the CA "model": suppression of soil disturbance, use of cover crops and crop rotations. However, in most of the situations, farmers have adopted parts of the CA package, ammowing many modalities of CA practice. For instance, as a result of economic constraints, farmers can suppress soil disturbance and keep the soil covered, but do not use crop rotations. In other cases, due to agro-ecological or cognitive factors, farmers may use crop rotations and cover crops, but make some sort of soil disturbance in some years. Based on the benefits of the CA "model" mainly regarding the amelioration of soil characteristics, the CA "model" has been largely promoted and many efforts to improve "farmers' practices in order to adopt the CA "model" has been carried out. However, there is very few information regarding the sustainability of CA farmers' practices.

The study must be carried out under a systems´ approach and have to take into account the different agro-ecological conditions and the different farming systems. The research should be comprises of 3 phases: a) identification and description of CA farmers´ practices; 2) understanding the rationale behind the practices; c) assessing the sustainability of these practices, from the technical, environmental and socio-economic perspectives. Phases a) and b) can be carried out through interviews and phase c) can be carried out through interviews, on-farm measurements and on-station experiments.

6.12 Development of CA systems less dependant on external inputs

The practice of CA generates a new dynamics, with the selection of some weeds, insects and diseases, and reduction of others. Some pests such as rats and slugs, which incidence is higher under CA, still lack studies. For weeds, insects and diseases management, crop rotations are the pillar of any IPM/IWM program; if crop rotations are not used in CA, the reliance on chemicals is higher, resulting in higher costs and negative environmental consequences. More research on both tropical and subtropical regions is required, aiming to develop alternatives to chemical control for CA, starting by basic studies aiming at understanding the dynamics of pests and weeds generated by the introduction of CA.

Besides policies for the promotion of the use of crop rotations, basic studies are necessary in order to better understand the new dynamics created by the practice of CA. Research on allelopathy, biological control and others aiming at decreasing the reliance on pesticides are necessary.

6.13 Technology development for some crops under CA

Despite the available technologies for the cultivation of cotton under CA principles, residues are buried by plowing in order to prevent the incidence of the pest *Anthonomus grandis.* Tobacco is cultivated under conventional systems by small-scale farmers at subtropical region, despite the efforts of tobacco companies in the promotion of CA for this crop. Although lacking scientific data, evidences from farmer's experiences indicate that the main reasons for the inappropriateness of tobacco to CA are: a) susceptibility of the crop to high soil moisture; higher incidence of slugs in CA mainly during wet periods and c) lack of broadleaves herbicides. Although the availability of technologies for potatoes, groundnuts and cassava, when these crops are harvested, great amounts of soil are disturbed. Development of harvesting equipment with lower soil disturbance is required.

6.14 Impact assessment of the adoption of GM crops and CA

Herbicide-resistant genetic modified soybeans have been largely used in Argentina and Brazil. The main driving force for the adoption of this technology is that it simplifies the cropping management and according to farmers, reduces operational costs. However, the adoption by farmers - although it is an important indicator- has been the only evidence of its benefits. Yet there is no scientific data available addressing the economic, social and environmental impacts of this technology in the short, medium and long term.

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