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TRM:

AGRICULTURE COMPONENT

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INTRODUCTION

Agricultural cultivation of sugarcane includes planting, crop treatments, the alternative mechanization for planting, harvesting and hauling, the recovery of the straw, and the agricultural management. With the perspective of the increase of cultivated area of sugarcane, a lot of alterations should happen in the agricultural sector. The expectation is that sugarcane burning will complete stops and green harvester will reach 100%, at least in the areas where mechanization is feasible, in the first stage (2015) and later in the whole area (2025). That will force the complete mechanization of sugarcane cultivation. New equipments for sugarcane harvesting is today in development and the perspective are that in 2015 they will be in use in experimental areas shifting some paradigms of sugarcane planting, harvesting, loading and hauling. It is expected that great part of the area planted with sugarcane in 2025 will uses this new mechanization concept that reduces drastically the negative impacts on the soil caused by the conventional system of cultivation.

TECHNOLOGICAL NEEDS AND CAPABILITIES

Products or technologies targeted

For better understanding of the text was divided in three parts, Planting, Harvesting and Straw Recovery. The Management of the agricultural component, as presented by Arraes *et al.* in the Chapter 15, Part 3, has been presenting enough technological production, lacking of access conditions, mainly to the mills of smaller economical capacity. The usage of advanced Information and Communication Technology (ICT) systems and formal management models in agriculture is much more harnessed to the mill organization background than to the technology availability, for this reason it is not presented here as being a technological demand.

Sugarcane planting

Sugarcane mechanization process begins with the planting. Today it is accomplished in the traditional way involving three stages. First, seedbed preparation, which often includes one or two passes by offset discs to cut up and incorporate the old crop, one pass of a subsoiler to eliminate compacted inter-row areas, another offset disking and a final open furrow implement before planting the next crop. Secondly, sugarcane harvesting in a different place for stem cutting which is the most common reproduction method. Each cutting must contain at least one bud and the cuttings are sometimes hand-planted, but billet planting is becoming common, since new equipments for sugarcane planting are turning available. The last operation consists of fertilizer distribution and furrow covering.

As mentioned in the previous chapters this process include too many operations and resulting in high cost, and its usefulness has been questioned, since its practices is not been justified through an increase in yield. To improve the sustainability of the system guaranteeing the increase in yield, reducing the production cost and the negative environmental impacts caused by the sugarcane production the planting system should be modified, and for this it will be necessary to invest in basic and technological research.

Two no competitive technological alternatives, which can contribute to reach the expected benefits, are presented.

Direct planting

Conservation agriculture (CA), which aims for zero tillage with the maintenance of a surface mulch to protect the soil surface and increase biological activity in the topsoil, is increasingly becoming recognized as an effective system of crop production that protects the soil from erosion while reducing the overall use of agrochemicals (Landers, 2005). Broadly employed in the production of cereals, no tillage as a cultivation method bringing economical and mainly environmental benefits, this cultivation technique is barely explored in the sugarcane production.

In this system the physical conditioning of the soil through intense and deep tillage to receive the bud of the sugarcane is replace by the preparation in rows, avoiding unnecessary disturbances and preserving the soil structure, always maintaining it covered with straw mulch. The biological activity, the incorporation of organic matter decomposition, the permanence of the roots of previous cycles and the reduction of the traffic is capable to maintain the soil in adequate conditions for a new crop with drastic reductions of the erosion, and production costs and increases water availability. In fact, the zero tillage system (ZT) is not simply a new technology, it represents a new philosophy, with a series of new basic values, that constitute a system of sustainable agriculture (Landers, 2005).

As described by several authors that studied the effects of ZT comparing with conventional tillage, ZT favours the formation of larger diameter soil aggregates, smaller disaggregation of the soil, larger water retention, larger rates of water infiltration, reduction in thermal soil flotation, and water economy also is improved since mulch reduces evaporation. Besides, the ZT provides reduction in the number of operations, personnel's available time and involved equipments, reducing the costs in approximately 47% in comparison with the conventional tillage and it can still contribute to increase the productivity (Sørensen and Nielsen, 2005).

The adoption of ZT in the cultivation of the sugarcane is theoretically possible, but for its implementation and complete adoption by growers it still depends on basic researches which must accomplish.

Technological bottleneck. The three main principles CA technique are: direct planting of crop seeds; permanent organic soil cover; and crop rotation. According to Landres (2005) the largest threat to the sustainability of CA is the no adoption of crop rotation for breakdown the cycles of pests, diseases, and weeds and the generation of appropriate amounts of mulch, or to increase the level of organic matter in the soil, promoting biological controls and reducing agricultural chemical use and costs of production.

Of these three factors the maintenance of the soil covering is not a technological problem, because the amount of trash generated during the process of harvesting green sugarcane is enough to guarantee the covering in appropriate levels to the practice.

The other two factors still need studies and technological development that allow the definitive implementation of CA for sugarcane. In the mechanization system for sugarcane, the traffic at each harvest is intense. The system uses heavy vehicles crossing a high percentage of the area, inducing in most of the cases to soil compaction in levels non favourable to plant root development. In this way the adoption of the ZT or any other CA system needs forcible to go through the alteration of the mechanization system, forcing the adoption of a traffic control system for the reduction of soil compaction.

The sugarcane is a semi-perennial crop, planted in rows spaced from 1.1 up to 1.5 m. The crop grows for 12-18 months before mechanical harvesting by the first time by cutting stalks at ground level. A ratoon crop regrows and is again mechanically harvested after a period of 12 months. Several harvests are taken from the initial planting, thus a crop cycle consists of a plant crop and on average five ratoon crops, cut annually. In this system the adoption of a CA has raised some concern regarding to soil-borne disease carry-over. Therefore studies of alternative systems of crop rotation and methods of natural control of pests and soil diseases should be led, relating the effect of the trash and of the new species in the new agriculture ecosystem formed by the technique of CA, in the soil pests and in the natural enemies and present entomopathogen.

Billet planting, seedlings, or pre-germinated plant

Although sugarcane produces seeds, stem cutting is the most common reproduction method. The stem is cut in billets with at least 3 buds each. The billet serves as energy reservation for the bud, guaranteed its emerging and nutrition until the development of the roots. In this system it is necessary to used between 4 to 12 $t.ha^{-1}$ of sugarcane billets[1] depending on the variety and planting method.

Technological bottleneck. The equipments used for the mechanical planting of sugarcane present low technological development. They are not capable to accomplish the necessary billets dosage control and there is lack of spacing uniformity, forcing to use larger density of buds for linear meter of furrow. In mechanical planting among 8 to 12 $t.ha^{-1}$ of billets are used, Janini (2008).

To solve the problem two alternatives can be investigate technically:

a) Improvements in the sugarcane planter, with the objective to incorporate new technology similar to the ones existent for cereals, where the seeds distribution control is accomplished accurately not only of the amount but the spacing as well, guaranteeing an uniform stand of the crop.
b) The planting system could be modified, based in two hypotheses: first that the sugarcane can grow starting from only one bud, and then it is possible to develop technology that allows to plant one bud instead of 3. The other hypothesis is that it is possible to develop the sugarcane plantation starting from cane seedlings.

New planting machines will be necessary in these systems that will also force the technological investment in this area.

Harvest

Sugarcane harvest in the current and expansion areas will be fully mechanized in the near future, just leaving the semi-automatic harvest for steepness areas and with difficult access. Sugarcane burning as a cleaning pre-harvest process should also be completely abolished.

Technological bottleneck. The harvesters available today in the market as well as the planters, present low technological index and new investments should be accomplished to improve their performance. These harvesters do not dispose, for instance, of efficient control system for base cut height control, that needs to be solved to avoid the excess of soil movement, as well as monitoring the losses, or the degree of vegetable extraneous matter that is taken within the load. Harvesters just harvest a single row at the time. The result is that each inter-row is trafficked twice by the harvester and at least twice by the tractor and the infield wagon. The equipment track widths are not standardized and it frequently mismatches crop row spacing practiced in the sugarcane. The outcome is that traffic traverses very close to the crop row, which can lead to knockdown of stalks, and traffic can also directly run over rows damaging the ratoons and resulting in yield loss.

Another challenge to be overcome by the mechanized harvest is its operational limitation in steepness areas above 12%; the support equipments, tractors and wagons, don not have that limitation, due to the possibility of track width adjustment. To reach 100% of sugarcane harvest mechanization, it is necessary to produce equipments capable to operate in steepness areas.

[1] Around 8 to 15 buds per linear meter.

The alternative of producing a cane with larger fibber percentage, the "energy cane" with up to 23% of fibber, will demand alterations in the design of the existent harvesters. The base cut system, feeding, cleaning and load transfer, today presents in the harvesters are adapted to harvest sugarcane with fibber percentage between 11 and 14%, alterations of this range will implicate in reduction of the operational capacity, increase of the total losses (visible and invisible) and reduction in the capacity of cleaning, consequently cost increase.

Straw recovery

The technology of billet harvest, now available, does not use the straw, which is burned or left over the soil depending on the crop system employed (burned or green). One of the principal challenges to make possible the use of this material is the development of a mechanical system of harvest that contemplates the recovery of the straw, at least partially, with cost and quality that make possible its energy use.

Technological bottleneck. The processes for straw recovery tested up to now have three alternatives. Alternative 1 involves the sun drying, followed by windrowing and bailing or chopped into small pieces transported to the mill and shredded. The windrowing process is responsible for the high amount of mineral extraneous matter in the recovered trash. The cost of the recovery of the trash overcomes 10 US$/t. The second alternative is denominated "integral crop harvest", because the cleaning system available in the harvester are turned off so that the billets, the straw and part of the tops are delivered by the harvester to the infield wagon, for later be separate in the mill, using a dry cleaning station. This second method, a little more economical, has its use limited by the distance from the agricultural area to the mill, because it increases the transportation cost due to the low density of the transported biomass. Another difficulty of this system is the lack of equipments that make dry cleaning an efficient process, with acceptable losses of row material. An alternative (Alternative 3), derived of the integral crop harvest is the part cleaning, which is obtained reducing the harvester cleaning efficiency. Consequently the amount of recovered straw decreases, but the load density transported to the mill increases. Table 1 presents the cost of recovery of straw as function of the system adopted.

It is observed, therefore the need for new withdrawal methods propose to assist the qualitative needs for the use of the straw as source of energy.

Figure 1 synthesizes the possible alternatives for the field management.

Critical system requirements (CSR)

Having defined the products and technologies that are the targets of roadmapping, the purpose of this section is to identify the critical qualities called critical system requirements (CSR). Here are identified the functional requirements and performance, featuring high-level dimensions to

TABLE 1 Straw recover cost (US$/t).

	Alternative 1	Alternative 2	Alternative 3
Straw at the mill*	9.61	23.23	2.74
Trash separation from cane	–	2.79	3.69
Trash processing	0.89	0.85	1.14
Total cost	**10.50**	**26.87**	**7.57**

* For alternative 1 following operations are included: windrowing, bailing, loading/unloading and transportation. For integral crop the operations are: internal transport (wagon) and transport to the mill (trucks).

Source: PROJECT BRA/96/G31, adapted from BRAUNBECK and ALBRECHT, Chapter 15, Part 3.

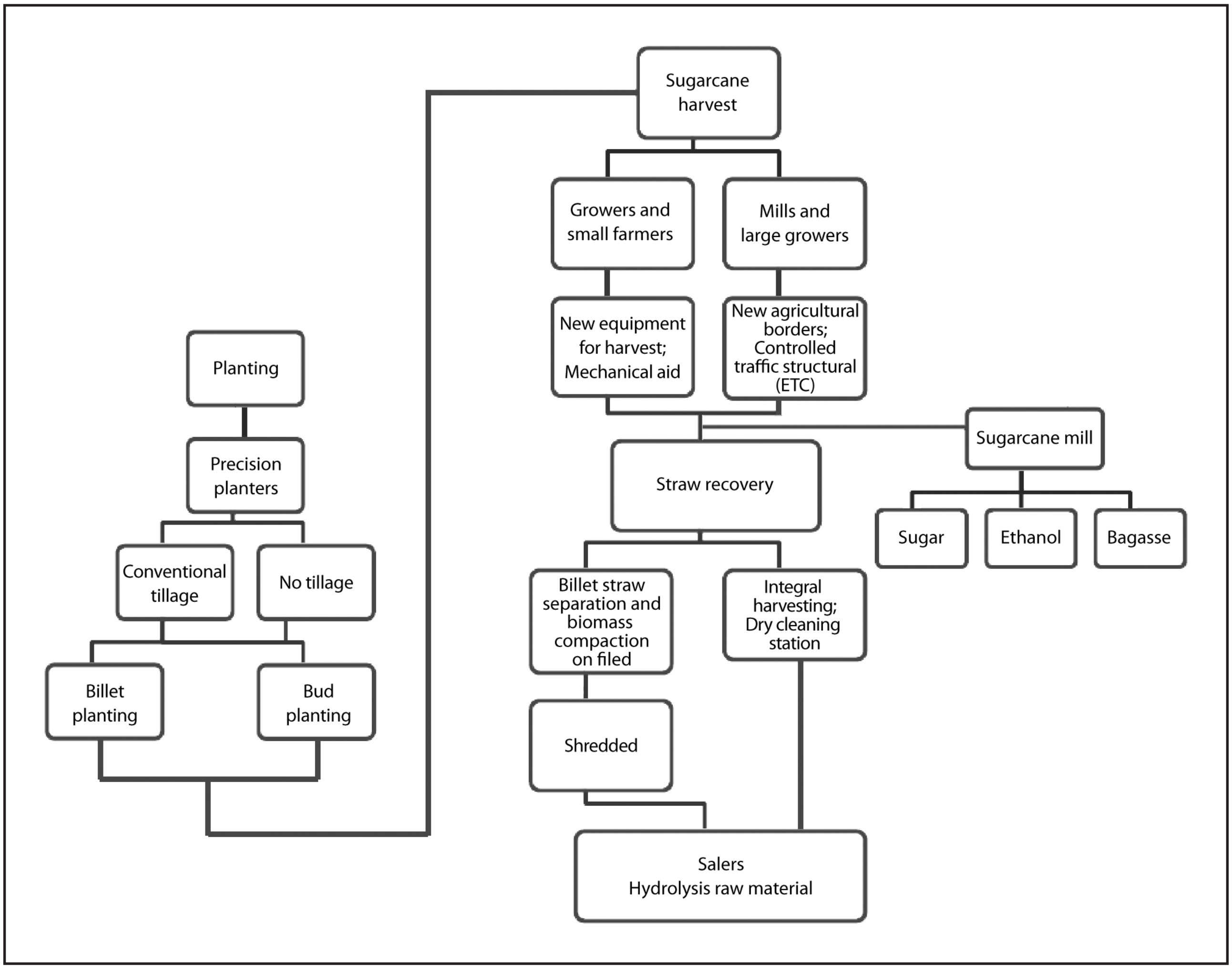

FIGURE 1 Alternative routes for sugarcane.

which the field management is related, as well as their goals over time in order to meet a set of strategic goals in terms of:

- productivity;
- cost;
- consumption of natural resources and energy balance ratio (EE/EU and GHG emissions).

In what it concerns to the agricultural sector productivity as a whole, the field management is here considered in terms of its contribution for the increase of the biomass recovery per hectare, starting in the actual of 81 $t.ha^{-1}$ (stalks only) to reach 150 $t.ha^{-1}$ (stalks and straw) in 20 years.

For the cost requirement, it is observed that the cost of biomass production is around US$ 22 to U$ 27[2] per ton depending on the area and it will, in the next 20 years, with the technology application, be reduced by 30%.

The environmental goals should be reached by the field management in terms of preservation of the environment, they should include the reduction of the negative impacts caused by the intensive soil preparation, reduction of the soil compaction and better use of the biomass produced for energy ends or preservation of the soil and water, and carbon recovery.

[2] The data are from a study realized by Escola Superior de Agricultura Luís de Queiroz (Esalq), and presented in (28/5/2009), during a national commission for sugar cane meeting of Brazilian Confederation of Agriculture and Cattle Breading (CNA).

A sustainable approach for agriculture demands a system that are not only environmentally friend, but also economically viable and socially responsible, Landers (2007). Important allies for such approach include the growers that adopt conservation systems and also governments and societies that support these growers. It is important to point out that in the agriculture the reduction of production cost means reduction in the final price to the consumer. Therefore the adoption of CA contributes not only for the conservation of the environment, but also with the reduction of the final price of the ethanol.

Table 2 summarizes the critical requirements of the system considered in the field management.

Major technology areas

Agronomy

The sugarcane in Brazil, as in many other countries, is harvested every 12-18 months, producing today an average 81 $t.ha^{-1}.year^{-1}$ (CONAB, 2009) and with perspective of reaching 130 $t.ha^{-1}.year^{-1}$ in 20 years. Annually approximately 20% of the total planted area is replanted, and only 30% is done using mechanical planters, in the remaining area the planting process system is semi-mechanized. Besides, traditionally 5% of the production area is reserved for "seed cane" production.

TABLE 2 Critical System Requirements for the Field Management.

CSR	Current	5 years	10 years	20 years (Vision)
Biomass Recovery of stalks ($t.ha^{-1}$)*	81	91	111	130
Biomass Recovery of straw ($t.ha^{-1}$)*	0	2	5	12
Total Biomass Recovery ($t.ha^{-1}$)	81	93	116	142
Biomass production cost (RV)**	1	0.96	0.80	0.69
Biomass production environmental impact	High	Medium	Medium	Low

* Considering the perspective of recovering at least 50% of the available straw.
** All the costs for planting, cultivation, harvesting and hauling of the biomass are included.

Planting cost of the sugarcane can be divided in two main components, the production of healthy and quality seedlings and the cost of soil preparation, furrow opening and closing, and fertilizers application. The operational planting cost depends fundamentally if this is accomplished mechanically or manually, but it is around US$ 400 to US$ 1,200 per hectare. This high cost is consequence of the great soil movement and high consumption of buds used by hectare.

Syngenta announced recently that the company is researching a new cane seedling with height of 3 or 4 centimeters, denominated "plene" with a previously treated bud to guarantee the vigor in the germination and to protect it against diseases and pests. This new technology should be commercially available in 2010. This technique promises significant progresses to the cultivation system. This new system can reduce in 15% the costs for the growers, and will result in a reduction of the request amount of seedlings for 1 (one) $t.ha^{-1}$. A specific planter will be necessary for it and it is been designed by a large tractor company.

The development of precision planters, for the conventional planting system or for the "plene" system, will make possible to reduce the amount of seedlings used per hectare, with consequent reduction of the area destined to seedlings production.

A new concept of sugarcane harvesting is emerging, without previous burning, that seeks the integral use of the plant, involving additional operations for detrashing and the compact disposition of stalk and trash for transportation. This approach has deep implications in the conventional harvest processes, associated with the production cost and mainly to the energy balance.

The straw is also one of the main components in the adoption of CA, indicating that this can just be partially recovered. Studies accomplished by the Center of Tecnologia Canavieira – CTC indicate that if at least 50% of the straw can be maintained in the field for soil protection the CA can be implanted with safety. The amount of biomass available after green harvest is on average 14 t.ha^{-1} (d.b.), with an insignificant amount being recovered today. The perspective is that the amount of straw produced by hectare should increase to 24 t.ha^{-1} in 20 years, this means that the straw production for energy use can reach up to 12 t.ha^{-1}, which means a contribution of 216 GJ per hectare. This energy potential is today superior to the available bagasse (175 GJ) and the possibility to use the bagasse for ethanol production through hydrolyses will demand the recovery of the straw to be used in the boilers.

Agricultural engineer

The adoption of CA goes obligatorily by the development of an efficient system of controlled traffic on the cultivated area. The project of Low Impact Mechanization for No-Till Farming, today being carried out in the Brazilian Bioethanol Science and Technology Laboratory (CTBE) is a fundamental piece for the adoption of this technology. It is expected that the first prototype will be in tests in 2010/2011 crop season and that in the following crop season it will be adopted experimentally by some mills, reaching around 100 thousand hectares in the year of 2015.

The principles of mechanized harvesting used today in Brazil do not assist satisfactorily the current solicitations in terms of efficient recovery of the biomass and long-term sustainability. Harvesting conducted with a single row harvester present high consumption of non renewable energy and low operational efficiency. It forces the traffic of harvesters and heavy equipments on more than 60% of the planted area, with consequent soil structural degradation and the reduction in crop yield. The restrictions that hold back the operation in great steepness areas are associated to the stability and lack of dirigibility. The cost of harvest-load-transport (HLT) today in Brazil represents 50% of the sugarcane production costs. Those items brought up the need of investment in technology.

Here again the strategy of controlled traffic (CT) presents as an innovation that can contribute in an effective way to the system sustainability. The CT leads to productivity earnings, reduction of operational and investments costs, makes efficient use of the rain waters, it reduces superficial water run-off and erosion, as well as improvement in the physical and fertility condition of the soil. The project of the a Controlled Traffic Structure (ETC), for sugarcane harvest consists of using a wide-frame structure with a large track width (10 to 12 m) as power unit. In the ETC a two row harvest device, using a base cutter with floating ability, will be attached. To clean the cane removing the leaves a new detrasher, based in friction principle, will be used. After passing through this device the cane is billeted and delivered into a wagon unit alongside the harvester. Having crop row spacing as a multiple of track width, guaranteeing that all traffic always occurs in the same position, the traffic zones will remain in place for several crop cycles. That will ensure longevity of the sugarcane plantation and enlarging the period among replanting.

As the ETC is destined for mill and growers with areas bigger than 10,000 ha, it is necessary to design a similar technology destined to small farmers and cane growers. The proposal of mechanical aid equipment for sugarcane harvest seeks exactly this. This equipment, capable to harvest several rows simultaneously, depends on operators that pick up the stalk over the platform and direct it to the cleaning system and storage. This equipment will guarantee rural employment and mainly the quality of life of these operators. Due to the balance in its dimensions and low centre of gravity, this equipment should be able to work in areas with inclination up to 40%. That together with its low acquisition and maintenance cost should assist the needs of most of the small cane growers, which will be forced to abandon the activity in other way.

The final cost of the recovered biomass is predominantly determined by four parameters associated to the involved processes that are: the investment level, the operational efficiency, the demand of energy and the final density of the raw material. Simpler systems, with smaller number of equipments, consuming less fuel and with high efficiency frequently result in smaller costs. The factor “load density” becomes more important as the distances between the production areas and the mill increases. In the case of handling of free material the bulk density can be increased reducing the size of the particles through chopping processes. However, the raise in density is limited and other compression systems have been presetting better results. For handling in natura material, with long fibbers, it is necessary to compress the material in bales and fastening to avoid relaxation of the material and corresponding density loss. Processes with larger pressures and temperatures, as the briquetting and the pelleting, get larger densities without fastening, but they increase the energy consumption significantly and reduce the operation efficiency.

To reach the goal of using the straw for energy in 20 years, it will be necessary the development of straw recovery and compression techniques, that can guarantee its transportation and use at competitive prices. Today the only viable technique to recover the straw consists of the integral harvest where the straw, tops and billets are delivered into the side wagon, for later separation at the mill at the dry cleaning station. This process requests high investments in dry cleaning station and is limited by the distance between the field and the mill, because the low density of the raw material. How to transform the energy potential of the straw in useful energy in the system is still technically not solved.

Electronics

The reduction of the amount of seedlings planted by hectare requests the development of specific equipments that execute the planting accurately, as well as it is accomplished for cereals, allowing, in the conventional system of planting, the reduction in up to 50% of the amount of seedlings necessary. It should be capable of planting 2 or 4 rows simultaneously and its position controlled be accomplished by precision agriculture system, through satellite guidance, guaranteeing the parallelism of the furrows. The depth control should be electronically accomplished in a way to assure a uniform germination.

Precision Agriculture (PA) technology certainly will have an important role in this context. Today partially being used the system of directional control trough navigation satellite (GPS-RTK) and data transmission system for fleet control through GPRS, should be improved contributing to the efficiency of the field operations. The tendency is that the cost of these equipments will be reduced and soon become a very spread technology. The application of fertilizers based the variable rate will be other great contribution to the sustainability of the system, reducing costs and the environmental damages.

Technology drivers

The conservative agriculture (CA) implementation in an efficient way also depends on the technological agronomic support. Parra *et al*. present in the Chapter 11 of the Part 3 the relationship of the technological areas that need to be developed for the efficient pest control which can benefited from the new cultivation system. According to the authors, studies should be conducted, relating the effect of the trash and of the decomposing species in the new ecosystem formed by the mechanical harvesting technique, soil pests, natural enemies and present entomopathogens; environmental impact of the chemical control for soil species; evaluation of the efficiency of the biological control on the pest. Bio-ecologic studies, monitoring methods and control alternatives should be initiate with intensity, because the control methods now used are empiric and with low efficiency. It is expected that the evolution of the pest control will go together with the rhythm of CA adoption.

The other problem is relative to the adoption of crop rotation due to nematodes and soil-borne disease. Sugarcane is a semi-perennial crop, typically grown in cycles of four–seven years, with consecutive ratooning, the maintenance of the trash in the soil creates a favourable atmosphere to the development of soils pests and diseases. The adoption of the practice of leguminous cultivation or traditional green fertilizer used during the reform period of the sugarcane plantation will not be enough to combat these pests (Dinardo-Miranda *et al*., 2008), demanding investments in technology (biotechnology) to reduce the problem to acceptable levels of pest infestation.

The sugarcane planters should be modified incorporating technology that allows them to plant accurately, guaranteeing with this a reduction of the amount of necessary buds for linear meter, contributing to the reduction of production cost by the smallest demand of seedlings and guaranteeing larger productivity, allowing the development more uniform stand.

The seedlings planting system proposed by Syngenta requests a new planter, now in development by John Deer. This technology should be available in parallel in order to f become feasible.

The MBI project carried on by CTBE pass through several engineering segments and presents some critical points in its development for being a project that breaks some paradigms of the conventional system of sugarcane cultivation. The proposal in development has been discussed with the technical and scientific community in workshops. It foresees several phases of the project that involves activities of different nature such as research and development of agricultural engineering, agronomics, mechanics, electronics and mechatronics, as well as administration and management for the field development.

The project of the Controlled Traffic Structure (ETC) involves 9 stages that are going from the project of the structure, traction systems and directional control, harvest equipment, storage system and load transferring, planting and cultivation to methodology of performance evaluation. The success of this project will contribute to two important lines in technological roadmap, planting and harvesting.

The mechanical aid for sugarcane harvest is being developed in a joint venture with UNICAMP-Agricef with the support of FAPESP and a prototype is expected for 2010. As well as the ETC this project involves specialists in structure design, mechanism, electronic control system etc. Its adoption in the field does not request alterations in the crop system employed, meaning low investment which contributes for its economical viability and adoption possibility by small and medium growers.

The implantation of precision agriculture system depends now mainly on agronomic studies related to soils and plants nutrition and on the development of data acquisition technology designed primarily for the sugarcane crop. The technology developed for cereals can be partly adapted to the sugarcane, guaranteeing in this way, the success of its application.

CA for sugarcane, as well as in cereals, abolishes conventional soil preparation, because the mulch maintenance and vehicles traffic reduction over the cultivated area guarantee reduction of the soil compaction and consequent yield increment. If the soil maintains along the years the appropriate structure for the development of ratoon without presenting compacted areas, the period for area replanting can be extend, from 5 to 6 years up to 8 or 10 years, depending on the variety. Replanting can be done directly over the remains of the previous crop, independently if it is sugarcane or other crop used for soil-borne disease reduction. In this way the adoption of CA contributes not only with the reduction of planting cost, but also to the reduction of the consumption of natural resources and energy balance.

In the next 20 years it is expected that the technological evolution of the mechanization in the sense of turning the sugarcane production more sustainable, present specific solutions for the sugarcane harvest without certain restrictions imposed by the tractors and the harvester, allowing the reduction of HLT operational cost. This objective can be reached through the reduction of the investments, production operational costs, crop losses, the intensity of the soil compaction and loosening processes, soil moisture content losses, the use of fossil fuels and its emissions, and the times lost by the equipments in the complex cycles of several interacting machines.

Each of the tables below shows the indicators to be pursued by each technology area in each CSR.

Gaps and barriers

The technological development of the sugarcane cultivation system has great potential to

TABLE 3 Technology drivers of the "productivity" CSR.

CSR	Productivity increase	Present	5 years	10 years	20 years (Vision)
Technology	**Agronomic**				
Indicator	*Availability of pest control for CA (%)*	n.a.	5	15	40
	Crop rotation systems specific for sugarcane (%)	n.a.	~	5	20
	Soil physical and chemical attributes and sugarcane yield determination (%)	n.a.	1	5	15
Technology	**Engineer**				
Indicator	*Precision plant system for sugarcane (%)*	n.a.	1	5	20
	New devices for sugarcane harvest (%)	n.a.	1	20	70
	Adoption of controlled traffic (%)	~	1	10	20
	Straw compression and transportation (%)	~	5%	20	30
Technology	**Electronic**				
Indicator	*On board electronics for precision agriculture application. (%)*	~	5	25	60
	Real time data transmission system (%)	1	10	50	80

Note: Percentages refer the technology driver's adoption for the productive sector.
• ~ Values non significant of some isolated initiatives.

TABLE 4 Technology drivers of the "cost" CSR.

CSR	Agricultural component cost	Present	5 years	10 years	20 years (Vision)
Technology	**Agronomic**				
Indicator	*Adoption of conservative agriculture (RV)*	1	0.95	0.9	0.9
Technology	**Engineer**				
Indicator	*Seedlings used per hectare (RV)*	1	0.95	0.9	0.85
	Vehicle traffic in cultivated area (RV)	1	0.95	0.85	0.6
	Raw material losses during harvest (RV)	1	0.95	0.7	0.3
	Straw recovery (RV)	1	0.95	0.85	0.6
Technology	**Electronic**				
Indicator	Reduction in the use of fertilizers (RV)	1	1	0.9	0.6
	HLT cost reduction (RV)	1	0.95	0.85	0.6

Note: RV – Reference value = 1

TABLE 5 Technology drivers of the "environment" CSR.

CSR	Environmental impact of agriculture component	Present	5 years	10 years	20 years (Vision)
Technology	**Agronomic**				
Indicator	*Soil compaction*	High	High	Average	Low
	Soil tillage	High	High	Average	Average
	Biologic control of pest and soil-borne disease	High	Average	Low	Low
Technology	**Engineer**				
Indicator	Number of seedling/bud used per hectare	High	Average	Average	Low
	Use of traffic control system	High	High	Average	Average
	Straw recovery	High	High	Average	Low
Technology	**Electronic**				
Indicator	*Use of fertilizers and herbicides*	High	Average	Low	Low
	Fuel consumption	High	High	Average	Average

contribute with the increment of ethanol productivity and reduction of the production cost in a sustainable way. However it was observed that there are few or reduced groups of researches with focus in this subject. The creation of CTBE was an important mark, but not enough to reach the wanted goals in medium and long period. CTC, although has contributed significantly with the development of the sector, as private organization, working with its associates' resources, have limited performance. It is then necessary to promote the formation of new research groups and to create conditions for searching youths' training.

There are also infrastructure and material resources deficiencies. The development of the agricultural goes obligatorily by field experiments that request big areas and years of study. The association with the privet initiative is indispensable through the productive sector (mills) as well as the manufacturers sector (machines, equipments, fertilizers etc.)

In the specific case of the precision planting system it is observed that although the need of developing more efficient planting equipments is recognized, researches results and available information show that this technology still needs a lot of investment to become available.

The adoption effective Conservative Agriculture, zero-tillage, as shown in this report, depends a lot on the development of other sectors of agronomy for its feasibility. Pests and diseases associated to the culture semi-perennial should be combated with investments in existent groups of researches to obtaining results in short period. Alternatives to be used for crop rotation should be study to contribute to the sustainability of the system.

Investments to implement precision agriculture are still very high and the results obtained by the research groups did not demonstrate the economical benefits of this technology yet. However it is observed that it has a great potential and in a short term period it should be adopted not only for its potential of production cost reduction, but also for environmental propose. For that it is necessary to develop human resources qualified to analyze and to interpret the results so that the technology potential can be explored, as it is happening with cereals.

FINAL CONSIDERATIONS

The agricultural cost of sugarcane production today represents about 60% of the total cost of the ethanol and sugar production; of this more than 60% refer to the agricultural component. It is observed that investments in R&D in the agricultural area are necessary and they can contribute to reach the goals of bioenergy production from sugarcane in terms of productivity increase, cost reduction and reduction of the environment impacts in the next 20 years.

Critical System Requirements shows the need to develop technological solutions that contribute with the improvement of the planting system, investing in precision planters, which will allow the cost reduction, through the reduction of the amount of buds per hectare, reduction of the area destined to the production of seedlings and obtaining a more uniform stand.

The technological option of zero-tillage following the example of what is done in cereals, comes as an attractive solution, but that requests development in the agronomy area, biology and engineering. The adoption of conservative agriculture goes obligatorily by the reduction of the traffic of vehicles on the agricultural area and this solution requests the break of engineering paradigms and the development of solutions for harvesting different from what it is available today in the market. Technological solutions to make possible the harvest of green cane and reduction of the traffic of vehicles should also be developed for the cane growers, with smaller cultivation areas and with smaller investment capacity. Equipments such as the mechanical aid for sugarcane harvest should be improved and make available commercially in few years.

The increase of the productivity in the biomass production for ethanol production include the straw recovery, that presents high energy potential, and that today is despised and left in the field. The recovery of at least 50% of the straw can be accomplished through two routes, the integral crop and separation at the dry cleaning station or through the separation and compression in the field for subsequent processing in the mill. Both need investments to turn them economically attractive.

The technological roadmapping of the agricultural component here presented is just an introduction to demonstrate that more deep study should be accomplished by researchers' groups and representatives of the private initiative, financed by public sector. Investment strategy on the part of the government for the development of the agricultural segment of sugarcane production for of energy use should be elaborated.

REFERENCES

Dinardo-Miranda, L. L.; Vasconcelos, A. C. M; Landell, M. G. A. *Cana-de-açúcar*. Campinas, IAC, 2008, v.1, p. 869-882.

Janini, D. A. *Análise operacional e econômica do sistema de plantio mecanizado de cana-de-açúcar (Saccharum* spp.*)*. Piracicaba, 2007. 148 p. Dissertação (Mestrado) – Escola Superior de Agricultura Luiz de Queiroz, 2007.

Landers, J. N. *Tropical crop–livestock systems in conservation agriculture*: the brazilian experience. Food and Agriculture Organization of the United Nations Rome, 2007, 106 p.

Sørensen, C. G.; Nielsen, V. Operational analyses and model comparison of machinery systems for reduced tillage. *Biosystems Engineering* 92 (2), 143–155 doi:10.1016/j.biosystemseng. 2005.06.014 (2005).