THE DEVELOPMENT AND IMPLEMENTATION OF THE BONSUCRO STANDARDS FOR PROMOTING THE SUSTAINABILITY OF SUGARCANE PRODUCTS

By

N. VIART\textsuperscript{1} and P.W. REIN\textsuperscript{2}

\textsuperscript{1}Head of Sustainability, Bonsucro
nicolas@bonsucro.com

\textsuperscript{2}Professor Emeritus, Louisiana State University, Consultant to Bonsucro
peterein@gmail.com

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Abstract

Pressure from the major users and traders of sugar and ethanol led to the formation of the Better Sugar Cane Initiative to develop certifiable standards for sustainable production of sugarcane. Following acceptance of the principles to be adopted, the processes involved in setting up and agreeing on a global standard are described. Over a period of about four years, a production standard, incorporating environmental, social and economic elements, and a chain of custody standards were developed and approved by the members. Now called Bonsucro, the organisation is funded almost entirely by its members, all involved directly or indirectly in the sugarcane sector, and operational and credible governance structures are in place. Certification is carried out by independent and approved certification bodies and experience to date in the certification of sugar and ethanol is described. Since it was established, the number of members of Bonsucro and the area under certified sugarcane has continued to grow steadily. The increasing acceptance of sustainability standards is being demonstrated with implications for all stakeholders. Possible limitations of a global metrics standard, challenges with respect to international recognition, and future improvements are finally discussed.

Introduction

There is a growing corporate move to address sustainable development and companies are beginning to appreciate that there are sound business reasons to adopt more sustainable production and processing practices. Managing social and environmental risks is important for growers, processors, traders and food companies due to regulatory pressures as well as shareholder and consumer expectations. Increasingly, environmental and social performance is affecting access to markets and to capital as well. As an indication of this, more corporations, including an increasing number of sugar mills, are reporting their results to stakeholders based on the Sustainability Reporting Guidelines proposed by the Global Reporting Initiative (GRI, 2011). Some environmental leaders in the industry have also reviewed their systems which enable them to become certified to ISO 14001 for environmental management. However, the latter addresses only environmental issues and ignores the social and economic elements necessary in sustainability initiatives.

There are various ways in which sustainability can be defined. A generally accepted definition would be along the lines of sustainable development providing for human needs without compromising the ability of future generations to meet their needs. The American Institute of Chemical Engineers defines sustainability as ‘the path of continuous improvement, wherein the products and services required by society are delivered with progressively less impacts upon the earth’ (Cobb et al., 2007).
Many companies are making enormous progress in advancing sustainability, with some adopting aggressive sustainability goals. Sustainability has become a significant driver of innovation, particularly for large corporations.

Sustainability involves the three components of environmental responsibility, economic return (wealth creation), and social development. Environmental and social concerns have been the main reasons for calls for the inclusion of sustainability criteria in policies regulating the international trade of biofuels (Londo and Deurwaarder, 2007). Although equally important, economic sustainability is sometimes overlooked. For the past 20 years, the WWF has been particularly responsible for initiating, promoting and sponsoring the establishment of sustainability standards for agricultural commodities, including sugarcane.

Largely at their initiative, the first meeting of like-minded stakeholders was held in 2005, which agreed on a collaborative approach to promoting sustainability and good practices in the sugarcane industry. This was the beginning of the Better Sugarcane Initiative, now referred to as Bonsucro.

The objectives of Bonsucro have been consistent since the first meeting, namely to provide social rights, limit the impact on the environment, and enhance the economic power of the sugarcane industry by promoting the use of a global metric standard, with the aim of continuously improving sugarcane production and downstream processing in order to contribute to a more sustainable future.

The global standard was developed in a way such that it could be applied in all sugarcane growing regions of the world. The standards aim at addressing sustainability issues which are common to the agricultural sector but also specific to the sugarcane industry (Clay, 2004; Rein, 2011; Rein, 2012).

**Development of sustainability standards**

Having set the objectives of the organisation, it was necessary at the outset to decide on how the standards would be used. Options include a self-assessment tool, trade guidelines, a reporting obligation, or a certification scheme. Following the example of other schemes for sustainable production of agricultural commodities, Bonsucro adopted the model of independent third party certification.

This model requires publication and maintenance of a set of documents outlining requirements that must be complied with by the operators and verification rules that independent, competent and accredited certification bodies must follow.

In designing the standard, the first step was the establishment of Principles, which are universal statements about sustainability and define the objectives of the standard. From the Principles flow the Criteria, that are the conditions to be met in order to adhere to a Principle. From the Criteria flow indicators that are measurable states that indicate whether or not associated criteria are being met. This is illustrated in Figure 1.

The five Bonsucro Principles are:

- Obey the Law
- Respect human rights and labour standards
- Manage input, production and processing efficiencies to enhance sustainability
- Actively manage biodiversity and ecosystem services
- Continuously improve key areas of the business

In article 18 of the EU RED 2009/28/CE (European Union Renewable Energy Directive) on the promotion of the use of energy from renewable sources (see [http://ec.europa.eu/energy/renewables/biofuels/biofuels_en.htm](http://ec.europa.eu/energy/renewables/biofuels/biofuels_en.htm)), the directive states that ‘the Commission may decide that voluntary national or international schemes setting standards for the production of biomass products contain accurate data for the purposes of Article 17(2) or demonstrate that consignments of biofuel comply with the sustainability criteria set out in Article 17(3) to (5)’.
In its decision 2011/439/EU, the commission recognised that Bonsucro EU certification can be used to demonstrate compliance with Article 18(1) of Directive 2009/28/EC and of Article 7c(1) of Directive 98/70/EC. Consequently, bioethanol certified against the Bonsucro standard can enter the EU market and be considered as contributing toward the obligation of each member state to reduce their GHG emissions. Therefore, one additional principle in line with the EU RED 2009/28 regulation was added, so that Bonsucro could become an EU recognised voluntary scheme. Through this enforcement mechanism, the EU commission accepts that companies certified against the standard of a voluntary scheme are considered compliant with the regulation.

These five principles are broken down into 20 criteria and 48 indicators. The standard is published on the Bonsucro web site: [www.bonsucro.com](http://www.bonsucro.com). There are five core criteria which must be satisfied to achieve compliance. These core criteria relate to obeying the law, satisfying the ILO labour conventions, minimum wages, biodiversity and stakeholder consultations. Compliance is achieved when the five core criteria are complied with and a total of 80% of all indicators are satisfied.

**Method of development of standards**

The process of developing standards and indicators has been transparent and inclusive. This is vital if the standards are to have international credibility and be adhered to. In this respect it was necessary for Bonsucro to engage widely with the stakeholders in the widest possible spheres of operation and to encourage participation through comments, suggestions and input of any kind. The stakeholders included farmers, producers, traders, end users, supporting industries, trade unions, social and environmental NGOs, indigenous groups, government, researchers, academics and certification bodies.

It was also important to ensure that participation reflected a balance of interests in all the issues and in the geographic scope. This is necessary to ensure that the standard reflects the reality of a whole sector, as well gain maximum support within the sector.

The International Social and Environmental Accreditation and Labelling (ISEAL) Alliance is a formal collaboration of international standard-setting organisations. It has developed a Code of Good Practice for Setting Social and Environmental Standards (ISEAL 2010). The code defines
effective standard-setting processes to enhance the credibility of the resulting standards. Adhering to such procedures result in progress towards social and environmental objectives, without creating unnecessary hurdles to international trade.

Bonsucro followed the ISEAL Code of Good Practices to ensure that the standards developed are robust and have the widest possible acceptance. Consequently, the following steps among others were adopted:

- Documented procedures for the process under which the standard is developed formed the basis of the activities of Bonsucro. These procedures were developed with the involvement of a balance of interested parties.
- Allowance was made for a complaints resolution mechanism for the impartial handling of any procedural complaints. All interested parties have access to this complaints resolution mechanism.
- A public review phase in the development of the standard is necessary, and included two rounds of comment submissions by interested parties, as well as direct consultations with potentially locally affected parties.
- Consensus was at the centre of the decision making process.
- All comments were recorded and a synopsis of how they have been dealt with is available to the public.
- Final standards are available in the public domain at www.bonsucro.com.
- Standards will be reviewed on a periodic basis for continued relevance and effectiveness in meeting their objectives and periodically revised as necessary. A review process must occur at least every five years.

**Certification protocol**

Bonsucro has developed a Certification Protocol for members and auditors that describes the process and procedures for certification against the Bonsucro standards. This includes:

- rules and requirements for the approval of Certification Bodies to certify operators
- rules and requirements for Certification Bodies to audit businesses against the Bonsucro standards, based on the ISO Guide 65 (now replaced by ISO 17065)
- certification requirements for economic operators to demonstrate compliance with the Bonsucro standards
- audit procedures for Certification Bodies to verify compliance with the Bonsucro standards.

The certification protocol incorporates two standards, the Production Standard and the Chain of Custody Standard. This is illustrated in Figure 2.

![Fig. 2—Bonsucro certification standards.](image-url)
Production standard

The ISEAL Alliance comments as follows on standards: ‘A good standard is equally applicable anywhere within its geographic scope and focuses on achieving outcomes rather than prescribing methods for reaching these outcomes (ISEAL, 2010). It is for this reason that Bonsucro has set metric indicators which measure impacts of activities (outcomes) rather than recording the existence of good practices.

Bonsucro has chosen to develop a metric-based standard rather than a best practice based standard. This means that most of the indicators are measurable targets which companies must achieve. It turns the focus on outcomes rather than means of achievement.

An advantage of the use of metrics is that they can be used as a means of assessing ongoing improvement, by monitoring how the values of the metrics change over time. It facilitates comparisons and benchmarking among producers but also reduces the risks involved with working with auditors, whose skills might be very disparate across companies and/or regions. Setting baseline values represents an on-going challenge. The standards have not been set up to be ‘best achievable’ but true reflections of what experts define as a minimum acceptable impact that can realistically be achieved by responsible operators across the globe.

It is important to differentiate between the Standards and Best Management Practices (BMPs). BMPs are a means to an end and not an end in itself. BMPs have been drawn up in many regions of the sugarcane world and are often locally adapted to support and improve efficiency of local producers. They do not identify or measure the impact of the activity considered. By nature, BMPs are constantly renewed by improvement delivered by research and development and availability of new techniques. BMPs do not belong in standards; they belong in workbooks and guidance documents (Clay, 2008).

The Bonsucro standards are consistent with ISO 14040 which incorporates Life Cycle Analysis (LCA). Indeed, the calculation of emissions using the techniques of LCA is incorporated in the Bonsucro standards. However, ISO 14040 looks only at environmental impacts, while the Bonsucro standards cover all sustainability issues including social and economic aspects.

To ensure producers receive sufficient guidance and to avoid inconsistent or biased calculation, Bonsucro has developed a Microsoft Excel based calculator, available to members and certification bodies. The calculator identifies exactly what data need to be collected and undertakes the calculations. The level of compliance is also automatically provided.

Bonsucro relied on expert groups with relevant and specific expertise. Each expert group was required to identify the key social and environmental impacts of sugarcane production and transformation, to assess how best to measure them, and finally to set the limits that must be met to contain these impacts. Three Technical Working Groups (TWGs) covered the three areas of (1) social and labour issues, (2) processing/mill issues and (3) agronomic practices. The membership of the TWGs covered all the disciplines involved and all major sugarcane producing regions.

Once the groups had identified impacts and developed a clear set of principles, criteria, indicators and verifiers, Bonsucro carried out stakeholder outreach meetings in ten different countries. Pilot studies were conducted to test the practicality of the standards and to verify the suitability of the values set for the indicators.

Chain of Custody Standard

Attached to the Bonsucro Production Standard, Bonsucro has issued a Chain of Custody Standard. The Standard set up requirements for the management of traceability claims along the entire supply chain.

The standard is based on the mass balance principle. Companies have to maintain an accounting system of certified input and output to demonstrate that they keep the balance null or positive over a set period of time. The accounting system must consider the content of pure sucrose or pure ethanol.
The requirements also look at the transfer of sustainability characteristics along the supply chain and set requirements for their identification. This ensures that shipments of products conform to the GHG (Green House Gas) saving requirements of the EU directive 2009/28/CE, which mandates a saving of 35% in GHG emissions relative to fossil fuels.

**Bonsucro organisation**

Bonsucro has been incorporated as a not-for-profit company in the UK, and has drawn up a set of procedures for good governance. In addition, Articles of Association have been established, which allow for open membership. Members are consumer companies (e.g. The Coca-Cola Company, Kraft, Pepsico, Unilever), commodity traders (e.g. ED & F Man, Cargill), NGOs (e.g. WWF, Solidaridad, Sucre Ethique), producer associations (e.g. Unica, Asocafé), local producers (e.g. Raizen, EID Parry, New South Wales Sugar) and oil companies (e.g. Shell, BP). All members are listed in a transparent manner on the Bonsucro website [www.bonsucro.com](http://www.bonsucro.com). Members are allocated to five classes of stakeholders that are defined in the membership rules: growers, industrials, intermediaries, end-users and civil society including NGOs.

Bonsucro is directed by a Board of Directors which is responsible for setting the strategy of the organisation. Membership is approved by the Board after a public consultation period of 30 days designed to collect comments from stakeholders on any potential member. Membership of the Board consists of at least two members of each group of stakeholders. The Board also has the ability to co-opt directors to provide expertise as necessary. The Secretariat’s function covers general management, engagement, finance and sustainability.

Bonsucro is funded entirely by its members, through the collection of membership fees (the level depending on the group of stakeholders) and certification fees. For specific projects, Bonsucro at times might also rely on grant money.

It has been established in practice that the cost of certification for a mill comes to an average of USD 0.17/t product (sugar or ethanol). This cost includes membership fees, cost of audits and certification fees. It does not include any investment which may be needed by producers to achieve certification, as this cost is specific to each individual case.

**Discussion**

A set of standards focussed on a single agricultural industry has a substantial advantage compared to similar standards that deal with commodities derived from various sources. Bonsucro gathers members that represent the sector as a whole. It fosters a high level of expertise that helps Bonsucro collect data to support the development and improvement of the standard. To that extent, the standard captures the reality and unique specifics of the sector and is able to offer relevant and efficient solutions to achieve sustainable production.

For example, the technical requirements captured in Section 3 of the Bonsucro Production Standard ([http://bonsucro.com/standard/production_processing.html](http://bonsucro.com/standard/production_processing.html)) and their objective values are only applicable to sugarcane farmers and mills. Actors in the sector can compare themselves to their peers. It also allows Bonsucro to carry out targeted communication campaigns, therefore being more efficient in carrying the sustainability message. Bonsucro acts as a networking platform within the sector to increase collaboration and knowledge sharing.

However, such focus also has its limitations, particularly for the adoption of the Bonsucro standards within the supply chain. Ethanol in particular is often mixed with products made from other feedstocks. The Bonsucro standard cannot be used to recognise the responsible production from any other feedstock. Participants in the supply chain may be more likely to use standards that have the ability to avoid the need for multi-certification and choose standards such as the Round Table for Sustainable Biofuel (details at [http://rsb.epfl.ch](http://rsb.epfl.ch)) applicable to all sources of biofuels.

**Results to date**

There are now nine accredited certification bodies approved to certify companies against the Bonsucro standards. In a system that relies on third party independent verification, it is critical that
assessments are carried out rigorously and that the assessors are trustworthy. To achieve this, Bonsucro focuses on training and verification. Training of auditors and producers has been actively undertaken in the most important sugar producing countries. Bonsucro acts as the accreditation body and has started controlling the activities of certification bodies by carrying out office audits and witnessing certification audits.

The first mill’s production was certified in June 2011. At the time of writing, 24 mills already have their production certified, representing just over 2.2% of the global area planted to sugarcane, producing 34 million tonnes of sugarcane, 2.5 million tonnes of certified sugar and 1.7 million m$^3$ certified ethanol. The 24 mills are located in Brazil, and in Australia. The way in which certified production has increased over time is shown in Figure 3.

**Fig. 3**—Development of Bonsucro certified sugarcane over time, in ha and t.

### Limitations of a metric system

The Bonsucro Production Standard uses a metric approach to quantify the impact of a producer’s activity. Most of the current indicators are basic values (e.g. emissions/t product, quantity of fertiliser used per hectare and per year, water usage/t product, added value/t product) and do not take local factors into consideration such as the quality of the soil or the scarcity of water. This has the effect of limiting the uptake of the standard in regions where natural conditions are extreme (e.g. naturally poor soil). Bonsucro will continue searching for new indicators that are independent of regional variations or that allow local factors to be taken into consideration.

As it is difficult and not desirable to rely only on compliance with metrics to demonstrate sustainability, good management practice requirements are essential and therefore are included in annex documents that are used during assessment. However, the final certification decision is currently only made on the percentage of indicators in compliance.

### Global acceptance

All countries have their own sets of regulations and laws governing environmental and social issues. Internationally recognised standards may be seen as one country or customs union prescribing the standards that a supplying country must meet as a condition for access to their markets. That might be seen as unfair by some exporters although, in some respects, it levels the playing fields among producers. Others may question whether linking such standards to trade is motivated by altruism or protectionism (Charnovitz et al., 2008).
However, some Bonsucro members use the standard as a tool to manage their business and reputational risks. The tool is indeed meant to be used across all regions. For the members, relying on a high level, global standard against which they can compare all their suppliers and report to their stakeholders is crucial.

Conclusions
A means of demonstrating sustainable production of sugar is being driven by a number of factors, including legislative requirements, investor expectations, consumer / market advantage and reputation and brand image. Awareness of sustainability issues is increasingly influencing business decisions.

The standards and indicators used in Bonsucro certification have proved to be robust and realistic. It is envisaged that a minor revision and update of the standards will take place in the near future to keep the standards relevant and practical. This will involve a further round of public consultation with all stakeholders as well as pilot testing.

A concern expressed by producers is that a need to meet sustainability standards is often linked to reporting and measurement requirements that are thought to soak up manpower, time and money. To avoid this misconception, credible standard setters must demonstrate the impact of adopting standards and achieve certification. These include:

- A means of self-assessment to demonstrate performance improvement;
- A means of benchmarking against others;
- Improved efficiencies and better returns on investment;
- For industries already meeting the conditions, a levelling of the playing fields in terms of meeting environmental and labour-related issues;
- Management of risk and liability; and
- Enhancement of brand image and reputation.

In the long run, it is expected that conforming to such standards could save money, as inputs such as energy and raw materials are used more efficiently, losses and wastage are minimised, and manpower is used more productively. On a global scale, certification provides stakeholders with the demonstrable assurance that products are produced in a sustainable way, ensuring among other things, that human rights are upheld, the environmental impact is limited and resources are safeguarded for this and future generations.

REFERENCES


LE DÉVELOPPEMENT ET LA MISE EN APPLICATION DE LA NORME BONSUCRO POUR LA PROMOTION DU DÉVELOPPEMENT DURABLE DES PRODUITS DE CANNE À SUCRE

Par

N. VIART et P.W. REIN

\(^1\)Responsable du Développement Durable, Bonsucro

nicolas@bonsucro.com

\(^2\)Professeur émérite, Université d'État de Louisiane, consultant de Bonsucro

peterein@gmail.com

MOTS-CLÉS: Développement Durable, Normes, Canne À Sucre, Sucre, Éthanol.

Résumé

LA PRESSION EXERCÉE par les principaux utilisateurs et négociants de sucre et d'éthanol a conduit à la création de Better Sugar Cane Initiative afin d'élaborer des normes pouvant être certifiées pour la production durable de la canne à sucre. Suite à l'acceptation des principes à être adoptés, les processus impliqués dans la mise en place et l'adoption d'une norme mondiale sont décrits. Sur une période d'environ quatre ans, une norme de production, intégrant des éléments environnementaux, sociaux et économiques, ainsi qu'une série de normes témoins ont été élaborées et approuvées par les membres. Maintenant appelée Bonsucro, l'organisation est presque entièrement financée par ses membres, tous impliqués directement ou indirectement dans le secteur de la canne à sucre, et des structures opérationnelles et crédibles de gestion sont en place. La certification est effectuée par des organismes certificateurs indépendants et agréés et l'expérience à ce jour dans la certification de sucre et d'éthanol est décrite. Depuis sa création, le nombre de membres de Bonsucro et la superficie sous culture de canne à sucre certifiée ont continué de croître régulièrement. L'acceptation croissante des normes de durabilité est démontrée avec des implications pour toutes les parties concernées. Les limitations possibles d'une norme mondiale métrique, les défis en matière de reconnaissance internationale, et les améliorations futures sont finalement discutés.

DESARROLLO E IMPLEMENTACIÓN DE LAS NORMAS BONSUCRO PARA PROMOVER LA SOSTENIBILIDAD DE LOS PRODUCTOS DE LA CANA DE AZÚCAR

Por

N. VIART y P. W. REIN

\(^1\)Jefe del Area Sostenibilidad, Bonsucro

nicolas@bonsucro.com

\(^2\)Professor Emeritus, Louisiana State University, Consultor de Bonsucro

peterein@gmail.com

PALABRAS CLAVE: Sostenibilidad, Normas, Caña de Azúcar, Azúcar, Etanol.

Resumen

LA PRESIÓN EJERCIDA por los grandes usuarios y comerciantes de azúcar y etanol condujo a la formación de la Iniciativa para una Mejor Caña de Azúcar creada para desarrollar normas certificables para la producción sostenible de caña de azúcar. Luego de aceptar los principios que deben adoptarse, se incluyen los procesos para el establecimiento y los acuerdos necesarios para la aceptación de una norma global. En cuatro años de trabajo se desarrolló y aprobó por los miembros
una norma de producción que incorpora elementos ambientales, sociales y económicos, junto con una cadena de normas de custodia. Hoy la organización se llama Bonsucro y es financiada casi completamente por sus miembros, todos involucrados directa o indirectamente en el sector azucarero y cuya organización administrativa y operativa es confiable y bien establecida. La certificación es realizada por organismos certificadores independientes previamente aprobados. Aquí se describe la experiencia acumulada en la certificación de azúcar y etanol. El número de miembros de Bonsucro y el área de caña de azúcar certificada ha crecido de manera estable desde su fundación. La creciente aceptación de las normas de sostenibilidad es demostrada incluyendo a todas las partes interesadas. Al final se discuten las posibles limitaciones en cuanto a una norma métrica global, los retos con respecto al reconocimiento internacional y la mejora para el futuro.

DESENVOLVIMENTO E IMPLEMENTAÇÃO DOS PADRÕES BONSUCRO PARA PROMOVER A SUSTENTABILIDADE DE PRODUTOS DE CANA-DE- AçÚCAR

Por
N. VIART e P. W. REIN
1Diretor de Sustentabilidade, Bonsucro
nicolas@bonsucro.com
2Professor Emérito, Louisiana State University, Consultor da Bonsucro
peterein@gmail.com

PALAVRAS-CHAVE: Sustentabilidade, Padrões, Cana-de-Açúcar, Açúcar, Etanol.

Resumo
A PRESSÃO POR parte dos maiores usuários e comerciantes de açúcar e etanol levou à formação da Iniciativa para Melhor Cana-de-Açúcar, responsável por desenvolver padrões certificáveis para produção sustentable de cana. Seguindo a aceitação dos princípios a serem adotados, descrevem-se os processos envolvidos no estabelecimento e na concordância acerca de um padrão global. Durante um período de cerca de quatro anos, foram desenvolvidos um padrão de produção, incorporando elementos ambientais, sociais y económicos, além de uma rede de padrões de supervisão, os quais foram aprovados pelos membros. Conhecida atualmente como Bonsucro, a organização é financiada quase inteiramente por seus membros, todos envolvidos direta ou indiretamente no setor de cana-de- açúcar, e possui estruturas de governança operacionais e confiáveis. A certificação é realizada por agências de certificação independentes e aprovadas e a experiência adquirida até o presente com a certificação de açúcar y etanol é também descrita neste trabalho. Desde seu estabelecimento, o número de membros da Bonsucro e da área com cana certificada tem crescido de maneira contínua. A crescente aceitação dos padrões de sustentabilidade está sendo demonstrada e têm implicações para todos os interessados. Por fim, serão discutidas as possíveis limitações de um padrão de métrica global, assim como os desafios enfrentados para o reconocimiento internacional e as melhorias futuras.
RISE AND FALL OF THE INDONESIAN SUGAR INDUSTRY

By

ARIS TOHARISMAN, TRIANTARTI and M. FADHIL HASAN

Indonesian Sugar Research Institute (ISRI)
atoharis@yahoo.com

KEYWORDS: Indonesian Sugar Industry, Sugar Productivity, Competitive Land.

Abstract

VALUABLE LESSONS CAN be learned from the long history of the Indonesian sugar industry. The Indonesian sugar industry began four centuries ago and became the second largest sugar exporter after Cuba. In 1930, Indonesia produced 2.9 million tonnes of sugar, of which 2.2 million tonnes were exported to Europe. The average sugar yield in Indonesia was approximately 14.8 t/h. However, the situation has changed drastically. Recently, Indonesia has become one of the largest sugar importers. In 2012, the average sugar yield was 5.9 t/h, only 40% of that achieved 80 years ago. This downturn was mainly due to non-conducive and inconsistent sugar policy which did not encourage on-farm and off-farm performance improvement. In addition, the shift of sugarcane production onto marginal land, due to competition with other commodities, displaced sugarcane areas for housing and industry, lack of support for research and development and difficulties with available skilled labour were all factors that led to the decline in the performance of the sugar industry. Revitalising the Indonesian sugar industry could be achieved in several ways: building new sugar factories and expansion of the sugarcane area, increasing sugar productivity, improving sugar quality, improving research and development organisation, improving human resource quality, producing potential co-products and allocation of government income from the sugar import tariff. However, evaluation and consistency in the long-term policy of the Indonesian government is needed in order to revitalise the Indonesian sugar industry.

Introduction

Sugar production in Indonesia began four centuries ago, and the country became the second largest sugar exporter after Cuba. The zenith was in the early 1930s when 179 sugar mills produced nearly 3.0 million tonnes of sugar annually, of which 2.2 million tonnes were exported to Europe.

The average sugar yield in Indonesia was approximately 14.8 t/h (Toharisman and Mulyadi, 2005). However, the situation changed dramatically. In the past 45 years, Indonesia has been a net sugar importer with domestic sugar consumption outgrowing production increases. Sugar imports grow annually.

This history of the Indonesian sugar industry should be an important lesson for many other producers. The fluctuation of sugar production in Indonesia was strongly associated with changes in sugar policy.

This paper attempts to analyse the various problems faced by the sugar industry in Indonesia, and which led to the country going from a net exporter to an importer. Some suggestions are made on how the policies in Indonesia can be improved for the benefit of the sugar industry.

Sugar production dynamics

The Java Island has been the main producer of sugar in Indonesia since the 1700s. During the period of Dutch colonisation, sugar production in Java increased remarkably. A part of this was
associated with the introduction of the ‘Cultuur Stelsel’ (regulation on cultivation system) in 1830 which forced farmers to provide land and labour for producing export crops. By 1930, Indonesia was the second biggest sugar producer and exporter in the world after Cuba (Nelson and Panggabean, 1991).

The sugar industry in Java was supported with cheap labour, a good irrigation system, fertile land, and excellent sugar machinery. All sugarcane areas were irrigated and totally managed by sugar companies. At that time, economic liberalisation was introduced to allow private investor involvement in sugar production. The policy led to significant expansion in sugarcane production areas, increased production and more sugar mills.

The world economic crisis in the late 1920s, followed by competition from beet sugar lowered the world sugar price. Based on the Chardbourne Agreement, sugar production from Java had to be reduced from 3.0 million tonnes to 1.4 million tonnes.

In order to comply with the agreement, the Dutch colonial government established Netherlands Indies Veereningde Voor de Afzet van Suiker (Nivas) in 1932.

This was the beginning of the sugar cartel in Indonesia. All produced sugar in Java had to be sold to Nivas. Sugar companies also had to pay a levy to Nivas. The levy was approximately 1.64% of the production cost. In addition, millers were forced to contribute to sugar research and development cost (1.36% from total production costs).

These factors led to a sharp decline in sugar production from 2.9 million tonnes in 1930 to only 492 600 tonnes in 1935. In the same period, the industry decreased from 179 to 35 sugar mills.

Along with the recovery of the world economy in the late 1930s, the sugar industry in Java began to rise again. In 1940, sugar production increased to 1.47 million tonnes. At that time, the Java sugar industry was the most efficient in the world, with an average sugar yield of 17.63 t/h and sucrose recovery of 12.79% (Table 1 and Figure 1).

<table>
<thead>
<tr>
<th>Year</th>
<th>Harvested area (ha)</th>
<th>Sugar Production (tonnes)</th>
<th>Sugar Productivity (t/ha)</th>
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<td>9.35</td>
</tr>
<tr>
<td>1955</td>
<td>72 426</td>
<td>813 344</td>
<td>11.23</td>
</tr>
<tr>
<td>1960</td>
<td>72 726</td>
<td>651 810</td>
<td>8.96</td>
</tr>
<tr>
<td>1965</td>
<td>87 408</td>
<td>775 950</td>
<td>8.88</td>
</tr>
<tr>
<td>1970</td>
<td>81 677</td>
<td>715 312</td>
<td>8.75</td>
</tr>
<tr>
<td>1975</td>
<td>104 777</td>
<td>1 035 052</td>
<td>9.88</td>
</tr>
<tr>
<td>1980</td>
<td>188 772</td>
<td>1 249 946</td>
<td>6.62</td>
</tr>
<tr>
<td>1985</td>
<td>285 529</td>
<td>1 707 048</td>
<td>5.98</td>
</tr>
<tr>
<td>1990</td>
<td>365 926</td>
<td>2 083 790</td>
<td>5.69</td>
</tr>
<tr>
<td>1995</td>
<td>420 951</td>
<td>2 084 077</td>
<td>4.95</td>
</tr>
<tr>
<td>2000</td>
<td>337 494</td>
<td>1 676 805</td>
<td>4.97</td>
</tr>
<tr>
<td>2005</td>
<td>381 786</td>
<td>2 240 000</td>
<td>5.87</td>
</tr>
<tr>
<td>2010</td>
<td>422 748</td>
<td>2 284 460</td>
<td>5.40</td>
</tr>
</tbody>
</table>

Source: ISRI (1930–2011)
During the 2nd World War, the Java sugar industry was destroyed. Many sugar mills were damaged, the number of sugar mills decreased from 159 to 49 and the management of sugar mills was taken over by the Indonesian government from the Dutch. However, most of the Indonesian managers were not adequately skilled in sugar production. Sugar trading was controlled by companies with a special relationship to government officials which in turn influenced sugar distribution and marketing allocation. At the same time, farmers were reluctant to lease fertile lands to sugar mills because of inadequate compensation. As a result, sugar production was only 650,000 tonnes per year and the average yield of sugar decreased to only 8.9 t/h.

During the period 1958–1968, sugar production in Java remained stagnant, while consumption continued to rise. In 1967, Indonesia became a net importer of sugar for the first time. During this time, the government adopted a new policy, by forming a syndicate of sugar marketing. This was not effective so the government appointed BULOG (National Logistic Agency) to handle sugar marketing. BULOG monopolised the marketing of sugar (Widyastuty and Haryadi, 2001).

As sugar imports continued to rise, the Indonesian government launched sugar self-sufficiency and price stability programs. To support this policy, the government took various steps such as improving the sugar trade system, providing suitable land to expand the sugarcane production area, and building new sugar mills outside Java (Arifin, 2008).

With this policy, sugar production increased by an average of 3% per year in the period of 1975–1980. This progress occurred primarily due to the increase of sugarcane production area (12.2% per year). Because irrigated and fertile areas were prioritised for rice production, sugarcane production increasingly occurred on low fertile dry lands. In addition, some arable land turned into non-agricultural uses such as industry and housing.

The proportion of the sugarcane area managed by farmers increased while that managed by sugar mills decreased (Table 2). The average sugar production during late 1980s–1997 was around 2.0 million tonnes per year. Unfortunately, due to the monetary crisis in 1997, followed by demonopolisation of BULOG, Indonesian sugar production dropped again to about 1.5 million tonnes per year.

An important turning point of sugar production was in 2004, when the government implemented ‘The Acceleration of Sugar Productivity’ program. This program provided financial support to carry out sugarcane replanting using prominent varieties and to improve cultivation
practices. As a result, sugar production increased to more than 2.0 million tonnes per year. At the end of 2010, the Indonesian government launched a program to revitalise old and inefficient mills, expand the sugarcane production area and to build new mills.

Since 2010, the sugar production has been around 2.4 million tonnes per year. For Indonesia to be self-sufficient, at least an additional 350 000 ha of production area is required which is currently difficult to obtain. In addition, government funding for sugar research and development decreased significantly.

The Indonesian Sugar Research Institute (ISRI), which provides high-yielding new sugarcane varieties and technologies, was facing financial problems which disrupted technology and variety delivery. The availability of skilled manpower in sugar production, both in the on-farm and off-farm sectors, continued to decline. Rehabilitation of old and inefficient sugar mills could not be carried out as planned. The program seems merely a concept and not delivering the anticipated improvement.

During the past 25 years, no new sugar mills have been built in Indonesia. Mill performance has not changed much over the past few decades. There appears to be a lack of interest for investment in the sugar industry

### Table 2—The development of sugarcane area managed by company and farmer (1930–2010).

<table>
<thead>
<tr>
<th>Year</th>
<th>Sugarcane area (ha)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Company (%)</td>
<td>Farmer (%)</td>
<td>Total</td>
</tr>
<tr>
<td>1930</td>
<td>196 542 (100.00)</td>
<td>0 (0.0)</td>
<td>196 542</td>
</tr>
<tr>
<td>1940</td>
<td>83 521 (100.00)</td>
<td>0 (0.0)</td>
<td>83 521</td>
</tr>
<tr>
<td>1950</td>
<td>27 721 (99.74)</td>
<td>71 (0.26)</td>
<td>27 792</td>
</tr>
<tr>
<td>1960</td>
<td>55 428 (76.53)</td>
<td>17 000 (23.47)</td>
<td>72 428</td>
</tr>
<tr>
<td>1970</td>
<td>69 172 (84.69)</td>
<td>12 505 (15.31)</td>
<td>81 677</td>
</tr>
<tr>
<td>1980</td>
<td>82 794 (43.86)</td>
<td>105 978 (56.14)</td>
<td>188 772</td>
</tr>
<tr>
<td>1990</td>
<td>117 278 (32.05)</td>
<td>248 648 (67.95)</td>
<td>366 926</td>
</tr>
<tr>
<td>2000</td>
<td>100 271 (29.71)</td>
<td>232 223 (70.29)</td>
<td>337 494</td>
</tr>
<tr>
<td>2010</td>
<td>105 654 (24.99)</td>
<td>317 094 (75.01)</td>
<td>422 748</td>
</tr>
</tbody>
</table>

### Revitalising Indonesian sugar industry

The new government program to revitalise sugar mills (SMs) was started in 2010 and aims at increasing total sugar production to 5.7 million tonnes in 2014. Currently there are 62 sugar mills which are spread across the production area. Fifty one SMs are operated by state owned companies, while 11 SMs are operated by private companies. Existing sugar factories are expected to produce 3.57 million tonnes of sugar and 2.13 million tonnes will be produced from new sugar mills.

The program aims at revitalising the Indonesian sugar industry in several ways:

**Building new sugar factories and expansion of sugarcane area**

For producing 2.13 million tonnes of additional sugar, it will need 10–25 new sugar mills having capacity between 6 000 to 15 000 TCD with expansion of 350 000 ha of sugarcane area. However, since 2010, no new sugar mills have been built in Indonesia. Some private companies are interested in building new sugar factories outside Java Island to support the Indonesian government programs but they find it difficult to secure sugarcane production area and/or face poor infrastructure in the potential new SM areas.
The Indonesian government should learn from the successful Brazilian sugar industry. The most significant Brazilian agricultural sector-specific policies have been those aimed at making credit available for production and investment. Underlying these policies have been strong State support and funding of agricultural research, the opening of Brazil’s agricultural frontier, and concurrent infrastructure investment. Brazilian policies implemented in the 1970s and early 1980s for land clearing provided the greatest incentives for sugarcane cultivation, propelling Brazil to its current position as the world’s largest sugarcane producer. To facilitate the opening of the frontier, the government provided subsidised credit for land clearing, machinery and production through regional programs (Valdes, 2011).

Hence, a program from the Indonesian government for building new sugar mills and expansion of the sugarcane area should be fully supported by government policy through credit or incentives to support investors, concurrent with infrastructure investment.

Increasing sugar productivity

The average sugarcane productivity in 2012 was 72.1 t/h with a CCS of 8.13%. The low sugar productivity was caused by low on farm technology adoption and low efficiency of sugar factories. One of the factors that caused low adoption of on farm technology is sugarcane farmer mistrust in the factory determination of CCS. This does not encourage the farmer to send good quality sugarcane to the mill and also results in low adoption of improved farming technology. Government regulation is needed to support the transparency of sugar factories on the determination of CCS % cane from the farmer and the application of core samplers in sugar factories.

Another aspect that could improve productivity is harvesting. An objective should be to ensure harvest to crush period of 48 h or less. For example, in Australia, there is an agreement between the farmers and sugar mills which include aspects such as harvesting, delivery to the mill, transport and handling, acceptance and crushing by the mill and cane payment (Anonymous, 2012). Each sugar factory should have a database of sugarcane farmers in their area with a cane delivery agreement to ensure supply of sugarcane to fulfill the milling capacity of the factory.

While increasing sugar mill efficiency can be done by increasing milling capacity, rehabilitation of some equipment from old SMs and management improvement especially for some state owned sugar factory companies is required.

Improving sugar quality

Currently, sugar produced by SMs in Indonesia is used to fulfil household requirements. Most plantation white sugar (PWS) produced in Indonesia uses the sulphitation process. The quality of sugar is variable resulting in two grades of PWS (PWS grade I and grade II). Currently, the price is the same for the two grades of PWS. Regulation is needed to differentiate the price of different grades of PWS which will create the necessary incentive for the SMs to produce high grade PWS.

Improving the research and development organisation

All the leading sugar industries in the world are supported by a strong research and development organisation (SASA, 2012; Anonymous, 2012; Valdes, 2011). Development of on farm and off farm technology for improving sugar productivity is the responsibility of the Research and Development Organisation. It is concerning that ISRI is facing financial difficulties.

This problem was created by changing ISRI to a private company responsible for its own funding. Income for the research centre comes mainly from consulting services and technology or research product sales.

The highest cost of research activities at ISRI is research on the development of new sugarcane varieties. However, there is no royalty system for sugarcane varieties in Indonesia now. New sugarcane varieties are freely available to farmers and SMs. Consideration should be given to the introduction of a royalty system to generate an income stream for ISRI.
Currently, ISRI doesn’t have an extension service that could facilitate the transfer of new technology to the users. ISRI staffs need to be trained as professional extension specialists to enable them to support effective technology transfer.

**Improving human resource quality**

The availability of skilled manpower in sugar production has continued to decline. There is an urgent need to investigate various ways that could assist in the human resource base. These could involve direct skill development, specific training programs or further education that is focused on the sugar industry.

**Producing potential co-products**

High sugar production is not the only potential target of a sugar mill. A sugar mill could be a healthy company and be very competitive through producing co-products. There are 7 co-products that have potential to be developed in Indonesia i.e. anhydrous ethanol, electricity, hydrous ethanol, baker’s yeast, citric acid, acetic acid and ethyl acetate (Toharisman and Kurniawan, 2012). However, the development of co-products should be supported by:

- Revitalising sugar mills with capacity more than 4 000 TCD.
- Increasing capacity of some potential SMs.
- Developing co-products at SMs having capacity more than 5 000 TCD, integrated with capital incentive or long period investment.
- Providing incentive for intensive market study of co-products in Indonesia.

**Allocation of government income from the sugar import tariff for funding revitalisation of the Indonesian sugar industry**

The Indonesian government has applied a 25% import tariff for sugar to protect the sugar industry. A study by Widyastuti and Haryadi (2001) showed that government income from this tariff was 381 billion rupiah. This government income should be allocated for various programs on revitalisation of the Indonesian sugar industry.

**Conclusion**

The long journey of the sugar industry in Indonesia shows that the dynamics that arise, especially in the production of sugar, are strongly associated with the changes in sugar policy. Conducive policies would increase sugar production and productivity. On the other hand, the non-conducive policy would lower sugar production and productivity.

Revitalising the Indonesian sugar industry could be achieved in several ways: building new sugar factories and expansion of sugarcane area, increasing sugar productivity, improving sugar quality, improving the research and development organisation, improving human resource quality, producing potential co-products and allocation of government income from the sugar import tariff for funding the revitalisation of the Indonesian sugar industry.

However, evaluation and consistency in the long-term policy of the Indonesian government is needed in order to reach the real target of revitalisation of the Indonesian sugar industry.

**REFERENCES**


LA CROISSANCE ET LE DÉCLIN DE L'INDUSTRIE SUCRIERE INDONESIENNE

Par

ARIS TOHARISMAN, TRIANTARTI et M. FADHIL HASAN

Institut de Recherches Sucrières de l'Indonésie (ISRI)
atohiris@yahoo.com


Résumé

DE PRÉCIEUX ENSEIGNEMENTS peuvent être tirés de la longue histoire de l'industrie sucrière indonésienne. L'industrie sucrière indonésienne a débuté il y a quatre siècles et elle est devenue la deuxième plus grande exportatrice de sucre après Cuba. En 1930, l'Indonésie a produit 2,9 millions de tonnes de sucre, dont 2,2 millions de tonnes ont été exportées vers l'Europe. La moyenne de rendement en sucre en Indonésie était d'environ 14,8 t/h. Toutefois, la situation a radicalement changé. Récemment, l'Indonésie est devenue l'une des plus grandes importatrices de sucre. En 2012, la moyenne de rendement en sucre était de 5,9 t/h, seulement 40% de celle réalisée il ya 80 ans. Cette baisse est principalement due à la politique sucrière non-favorable et incohérente qui ne favorise pas l'amélioration des performances à la ferme et hors ferme. En outre, le transfert de la production cannière sur des terres marginales, en raison de la concurrence avec d'autres produits, le remplacement des périmètres sucriers par des zones résidentielles et industrielles, le manque de soutien à la recherche et au développement et les difficultés avec la main-d'œuvre qualifiée sont autant de facteurs qui ont conduit à la baisse de la performance de l'industrie sucrière. La revitalisation de l'industrie sucrière indonésienne pourrait être réalisée de plusieurs façons: la construction de nouvelles usines et l'extension du périmètre sucrier ; l'augmentation de la productivité ; l'amélioration de la qualité du sucre, de l'organisation de la recherche et du développement, et de la qualité des ressources humaines ; la production potentielle de coproduits et la répartition des revenus gouvernementaux du tarif d'importation de sucre. Toutefois, l'évaluation et la cohérence de la politique à long terme du gouvernement indonésien sont nécessaires afin de revitaliser l'industrie sucrière indonésienne.
AUGE Y CAÍDA DE LA INDUSTRIA AZUCARERA DE INDONESIA

Por

ARIS TOHARISMAN, TRIANTARTI y M. FADHIL HASAN

Instituto Indonesio de Investigación de Azúcar (ISRI)
atoharis@yahoo.com

PALABRAS CLAVE: Industria Azucarera Indonesia, Productividad De Azúcar, Competitividad.

Abstract

LA LARGA HISTORIA de la industria azucarera de Indonesia puede dejarnos lecciones valiosas. Esta industria tuvo sus comienzos hace cuatro siglos y llegó a ser el segundo exportador a nivel mundial, después de Cuba. En 1930, Indonesia produjo 2.9 millones de toneladas de azúcar de las cuales 2.2 millones fueron exportadas a Europa. La productividad promedio era de aproximadamente 14.8 t/h. Sin embargo, la situación ha cambiado drásticamente. Recientemente, Indonesia se convirtió en uno de los importadores de azúcar más grandes. En 2012, la productividad promedio fue de 5.9 t/h, solo el 40% de lo que se obtenía hace 80 años. Esta caída se debió principalmente a políticas inconsistentes y poco propicias que no promovieron mejoras en el desempeño dentro y fuera de los campos. Además, muchos factores como el traslado del cultivo a áreas marginales originado por la competencia con otros productos y que desplazó el uso de la tierra para fines de construcción de vivienda e industria, la falta de apoyo para realizar investigación y desarrollo y las dificultades por mano de obra capacitada condujeron a la disminución del desempeño de la industria azucarera. Existen muchas formas de revitalizar la industria azucarera indonesia: construir fábricas nuevas y expandir el área de cultivo, incrementar la productividad del azúcar, mejorar la calidad del azúcar, mejorar la organización de la investigación y el desarrollo, mejorar las competencias del recurso humano, trabajar en la producción de co-productos potenciales y adjudicar fondos gubernamentales provenientes de la tarifa de importación del azúcar. Sin embargo, es necesario evaluar la política de gobierno a largo plazo así como su coherencia para renovar la industria azucarera de Indonesia.
ASCENSÃO E QUEDA DA INDÚSTRIA DE AÇÚCAR DA INDONÉSIA

Por

ARIS TOHARISMAN, TRIANTARTI e M. FADHIL HASAN

Instituto de Pesquisas em Açúcar da Indonésia (ISRI)
atoharis@yahoo.com

PALAVRAS-CHAVE: Indústria Açucareira da Indonésia, Problemas, Produtividade de Açúcar, Concorrência por Terra.

Resumo

LIÇÕES IMPORTANTES PODEM ser aprendidas da longa história da indústria açucareira da Indonésia. A indústria de açúcar da Indonésia teve início há séculos e tornou-se a segunda maior exportadora de açúcar, em seguida à Cuba. Em 1930, a Indonésia produziu 2,9 milhões de toneladas de açúcar, das quais 2,2 milhões de toneladas eram exportadas para a Europa. A produtividade média de açúcar na Indonésia era de, aproximadamente, 14,8 t/h. Entretanto, a situação mudou drasticamente. Recentemente, a Indonésia tornou-se uma das maiores importadoras de açúcar. Em 2012, a produtividade média de açúcar era de 5,9 t/h, apenas 40% dos índices atingidos há 80 anos. Essa reviravolta é explicada principalmente por uma política do açúcar não conducente e incoerente, que não estimula a melhoria do desempenho nas propriedades produtoras e fora delas. Além disso, a mudança da produção de cana para terras marginais, devido à concorrência de outras commodities, áreas de cana deslocadas para habitação e indústria, falta de incentivo à pesquisa e ao desenvolvimento e as dificuldades com a mão de obra qualificada disponível foram fatores que levaram ao declínio no desempenho da indústria de açúcar. Revitalizar a indústria de açúcar da Indonésia pode ser alcançado de várias maneiras: pela construção de novas fábricas e a expansão da área de cana, pelo aumento da produtividade de açúcar, pela melhoria da qualidade do açúcar, pela melhoria da organização de pesquisa e desenvolvimento, pela melhoria da qualidade dos recursos humanos, pela produção de coprodutos potenciais e a alocação da receita do governo do imposto de importação de açúcar. Dessa forma, é necessário que se realize uma avaliação e que haja constância na política de longo prazo do governo da Indonésia para revitalizar a indústria açucareira desse país.
CHANGING LANDSCAPE OF SUGARCANE PRODUCTION—NEED FOR A PARADIGM SHIFT IN SUGARCANE RESEARCH AND DEVELOPMENT

By

M.C. GOPINATHAN
E.I.D. Parry (India) Ltd
Research & Development Centre,
145, Devanahalli Road, Off Old Madras Road,
Bangalore 560 049, India
gopinathan@threei.in

KEYWORDS: Sugarcane, Research & Development, Productivity, Innovation.

Abstract
SUGARCANE PRODUCTION IS undergoing unprecedented structural changes, facing complex challenges of population growth, economic development, globalisation of trade, increasing competition of new demands of bio-energy, climate change and impacts of various biotic and abiotic stresses. World demand for sugar is expected to double by middle of this century. Sugarcane as a multiple feed stock for production of sugar, power, alcohol, bio-fuels, bio-polymers and bio-pharmaceuticals will sustain further demand. Most of these demands and growth are likely in the tropical and subtropical farming systems in Africa, Asia and Latin American countries. These systems are complex, highly heterogeneous, and dominated by small, resource poor farmers. As the expansion of area is limited in most of the cane growing countries except Brazil and some parts of Africa, increased production is likely to come from the increase in farm productivity. An analysis of 50 years data from major sugarcane growing areas indicated that, irrespective of impressive growth of the sugar industry for the last four decades, cane yield growth has continued to stagnate or decline during the last two decades. The key driving force for increased productivity comes from agricultural research and innovations at various levels of the value chain. Large numbers of studies have reported a positive contribution of agricultural research to productivity. However, in recent years, a marked slowdown in public funding for agricultural R&D has been evident. Further, developed countries agricultural research agendas have shifted from simple productivity improvement to enhancement of complex attributes with a focus on production systems (sustainability). Private R&D investment in sugarcane is limited in few countries such as Brazil and Australia because of various IPR issues. Attracting and retaining young talent for research is also becoming difficult. These challenges call for a paradigm shift in the approach to sugarcane research. The ecosystem research model proposed emphasises strong partnership of all stakeholders, innovators and idea creators to revitalise and synergise the sugarcane R&D landscape.

Sugarcane—present scenario
Traditionally, sugarcane has served as a source of sugar for food, molasses or juice for alcohol, and fibre for fuel for hundreds of years. Presently, sugarcane is grown in more than 100 countries with a sub-tropical and tropical climate representing diverse continents, populations, demography, culture and economic development. The socio-economic contribution of sugarcane production and trade are significant in providing direct and indirect employment and livelihood for
millions of people around the world. The share of sugar production from sugarcane consists of more than 80% of total sugar produced globally. Sugarcane area under cultivation increased 2.6 fold and production 3.8 fold in the period from 1950 to 2010. Regional composition of cane area, production and growth also shifted dramatically. South America, Asia and Africa became major growth centres.

Among the countries, Brazil occupies number one position (42%) in terms of cane production followed by India (17%) and China (6%). Productivity growth was mainly concentrated in the top ten cane producing countries such as Brazil, India, China, Thailand, Mexico, Pakistan, Columbia, Philippines, Australia and Argentina and the combined total of their share increased from 59% in 1961 to 82% in 2010 (Figures 1 and 2, Table 1). The rest of the world’s contribution declined from 41% to 18% for the same period (Figure 2).

![Fig. 1—Cane production from 1961–2010 in top 10 sugar producing countries. Data source: FAO, 2012.](image1)

![Fig. 2—Cane production percentage from 1961–2010 in top 10 countries in comparison with the world. Data source: FAO, 2012.](image2)

<table>
<thead>
<tr>
<th>Regions/Countries</th>
<th>Area, production, yield in 2010</th>
<th>Annual growth rate percent 1961–2010</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Area(million ha)</td>
<td>Production (million t)</td>
</tr>
<tr>
<td>Africa</td>
<td>1.58</td>
<td>89.59</td>
</tr>
<tr>
<td>South America</td>
<td>10.41</td>
<td>822.03</td>
</tr>
<tr>
<td>Rest of America</td>
<td>2.18</td>
<td>141.81</td>
</tr>
<tr>
<td>Asia</td>
<td>9.25</td>
<td>624.10</td>
</tr>
<tr>
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<td>World</td>
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<td>717.46</td>
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<td>India</td>
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</tr>
<tr>
<td>Thailand</td>
<td>0.98</td>
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<td>Pakistan</td>
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<td>Argentina</td>
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<td>Top Ten Countries</td>
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<td>1418.78</td>
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<tr>
<td>Rest of World</td>
<td>4.81</td>
<td>292.31</td>
</tr>
</tbody>
</table>
Sugar consumption has been growing fast in the developing countries, which now account for 72 per cent of world consumption (from 49% 30 years ago). In contrast, sugar consumption has grown very little in the industrial countries, and has declined in the transition countries in the 1990s (OECD/FAO, 2011).

Emerging challenges

By the year 2050, it is projected that the global population will likely reach nine billion from the present seven billion (UN, 2012). Most of this growth will be in Africa, Asia and South America, the major sugarcane growing regions of the world. In contrast, in the developed world (Europe, USA and Japan), where most of the sugar beet is grown, the demographic growth will change as populations on average may either decline, or remain the same.

Economic growth projections also indicate seismic shift and changes in the present world order with dominance of emerging economies of China, India, Brazil, a few South East Asian countries and a few African countries (ADB,2011). With higher incomes, market access, foreign direct investments, supermarket chains, information revolution and diverse taste habits of these countries, dietary patterns will shift from low- to high- value cereals, poultry, meats, sugar, fruits and vegetables.

The combined effects of all these changes are expected to result in almost a doubling of global demand for food, feed and fibre in 2050 (FAO, 2011). Sugar demand is also expected to grow from the present 160 to 320 million tonnes or more. All these increased demands will have to be met in competition with food crops which share the same space, water and other resources of agriculture.

During the past 30 years, Brazilians have demonstrated that using sugarcane-based biofuels for transportation can reduce energy dependency on fossil fuels and emission of greenhouse gases (Matsuoka et al., 2009).

Realisation of the effective role of bio-ethanol from sugarcane for mitigation of CO₂ emissions, reduced energy dependency, diversified fuel supply, employment generation, increased livelihood opportunities and rural development have led other sugarcane producing countries to also initiate policies, legal frameworks, mandates, directives, and to develop instruments for research, development, production and trade of bio-ethanol (Gopinathan and Sudhakaran, 2009; Timilsina et al., 2012). Hence, sugar production is likely to face increasing competition from the bio-ethanol market for the same raw material.

Recent research results and pilot plant studies in biotechnological and bio-process engineering have demonstrated that the biomass can be tailored, in a processing factory, into various industrial polymeric raw materials with a wide range of products similar to a petroleum refinery known as a ‘bio-refinery’ (Arruda, 2011). Hence, sugarcane as a multiple feed stock for production of sugar, energy, bio-fuels and bio-polymers would keep up the world aggregate demand for sugarcane for all uses.

Growth in sugar production in the past five decades has come largely from area expansion (CAGR 2.03%) and to a limited extent from yield increase (CAGR 0.74%). This is in contrast to major food crops where productivity growth largely came from yield increase during the same period (Table 2).

Sugarcane showed one of the lowest yield growth rates among the major crops. A regional analysis shows most of these growth areas occurred in South America (3.3%), Africa (2.71%) and Asia (1.89%). Country analyses indicate that Thailand (5.76%), Brazil (3.94%) and China (3.65%) growth in area was higher than the global average (Table 1).

In future, the potential for area expansion exists only in Brazil and a few African countries. Large numbers of experts indicate rapid expansion of sugarcane in these areas could potentially reduce the availability of arable land for the cultivation of food and feed crops, causing a reduction in food production.
in their supply and an increase in food prices and a threat to food security (Ceaser and Timilsina, 2012). Hence, future growth will have to be more productivity-driven. This means most of the sugar needed to meet increased demands of 2050 must be produced from existing cane growing areas of Asia, Africa and South America without much area expansion.

Agricultural ecosystems of these regions are complex, highly heterogeneous, fragile, and generally low in productivity, and dominated by small-scale, resource poor farmers, except where sugarcane is mainly cultivated under large plantations (Hazell, 2011).


<table>
<thead>
<tr>
<th>Crops</th>
<th>Annual growth rate percent 1961–2010</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Area</td>
</tr>
<tr>
<td>Wheat</td>
<td>0.13</td>
</tr>
<tr>
<td>Maize</td>
<td>0.89</td>
</tr>
<tr>
<td>Rice, Paddy</td>
<td>0.66</td>
</tr>
<tr>
<td>Soya beans</td>
<td>3.04</td>
</tr>
<tr>
<td>Groundnuts</td>
<td>0.75</td>
</tr>
<tr>
<td>Sugar beet</td>
<td>−0.79</td>
</tr>
<tr>
<td>Sugarcane</td>
<td>2.03</td>
</tr>
</tbody>
</table>

An assessment of yield of sugarcane for the past fifty years shows cyclical with marginal growth improvement compared with most of the food crops (Figures 3, 4 and 5). Region-wise, the highest yield growth percent was in South America (0.99%) followed by Asia (0.75%) and Oceania (0.52%).

Africa, after a period of growth, showed negative yield growth. Among the top ten cane producing countries, Columbia (1.76%), Brazil (1.23%) Argentina (1.30%), Thailand (1.64%) and Pakistan (1.14%) showed high growth rates compared to lower growth rates of India (0.76%), Mexico (0.54%), Australia (0.46%) and Philippines (0.45%). To achieve projected cane production for the next 40 years and keeping global acreage flat, yield growth would need to be doubled from present 0.74 to at least 1.75% annually.
Achieving such productivity increase will not be easy, as availability of natural resources such as land and water, which are critical components of agriculture, are declining at a faster rate than predicted. In addition to land use changes, deforestation, degradation of soil, and natural resources are approaching the tipping point in a large number of countries (FAO, 2011).

Sugarcane competes with other food crops for irrigation in most of the cane growing areas. Most worrisome are cane growing countries such as China, India, Pakistan, Near East and in the North African region where over exploitation of groundwater aquifers has led not only to growing water scarcity for agriculture, but also to acute scarcity of drinking water (WRG, 2010).

Further, potential for negative off-site impacts by the sugar supply chain on the ecology, has led to ever-increasing scrutiny of current sugarcane production systems from regulatory agencies, local communities and consumer groups on environmental sustainability of sugarcane (IFC, 2011).

Various projections on climate change indicate that climate change is accelerating and the direct and indirect effects of climate change on agriculture will manifest throughout the economic system, altering prices, production, productivity investments, food demand, food consumption and ultimately human well-being (Word Bank, 2010). Being a C4 crop, sugarcane production systems will have to increasingly cope with the effects of climate change, notably higher temperatures, greater rainfall variability and more frequent extreme weather events such as floods and droughts (Nelson et al., 2010).

Strategic option—Productivity improvement through continued investment in R&D

To meet demands of coming decades, sugarcane productivity needs to be doubled within the limited availability of natural resources, severe environmental pressures and climate change impacts. The key driving force for increased productivity for crops comes from agricultural research and innovations at various levels of the value chain. Hundreds of country-specific studies from different time periods, using diverse evaluation methods and models, reported highly positive (range of 40 to 60 percent per year) contributions of agricultural research to agricultural productivity (Alston et al., 2000 and 2010).

These studies also reveal a strong association between agricultural productivity improvements in a given year and the extent of spend on agricultural research and extension during the previous 30 years and more. Worldwide, spending on public agricultural R&D (including the government, non-profit and higher education sectors) increased to USD 24 billion in 2005.
compared 14.2 billion in 1981 on the basis of purchasing power parity (PPP). It grew faster in developing countries (from an estimated 41% share in 1980 to 53% share). China and India accounted for 29.1% of all expenditure on public agricultural R&D by developing countries, a substantial increase from their 15.6% combined share in 1981.

A notable aspect of these trends is slowdown in the pace of growth of public agricultural R&D spending (0.38% during 1990 and the subsequent period compared to 1.89% per year average during 1980s), especially among the rich countries (Alston et al., 2010; Bientema and Elliott, 2011). Significant research investments, particularly in plant breeding, plant pathology, entomology and agronomy are required just to maintain productivity achieved at previous levels (Alston et al., 2010).

The international agricultural research system is struggling to redefine its own future strategies, raising its ability to support and strengthen its national public partners (Spielman, 2007). Further, developed countries, which are rich and self sufficient in food, are shifting agricultural research agendas from productivity improvement to complex attributes such as enhancement of food, safety, production systems (organic, Bonsucro, sustainable, fair trade etc) and climate change.

The private sector has emerged as a major force in the production and ownership of new generation technologies in the areas of plant biology, information and communications, and access to these technologies by developing countries will depend on their ability to attract and stimulate private investment in R&D and intellectual property systems (Naseem et al., 2010).

Historically in sugarcane, research and extension was predominantly a state or public funded research function in most of the sugarcane growing countries such as India, Australia, USA, Brazil etc. These investments paid off in terms of producing large numbers of high yielding varieties and technologies adaptable to specific agro-climatic conditions. Much of the progress in increasing crop productivity has come from conventional breeding which usually takes up to 10 to 15 years of breeding, selection, release and extension practices (Hogarth et al., 1997; Snyman et al., 2008).

Unlike in other crops, sugarcane productivity was mainly dependent on public research. Investments by multinational seed or biotech companies in sugarcane research were limited. Lack of structured seed production systems, multiple ratooning of sugarcane and non-implementable IPR systems distracted investment by the multinational companies.

Efforts to even apply bio-technological tools to understand the sugarcane crop and enhance its productivity, came from mainly academic institutions and public research institutes such as BSES, SASRI, Queensland University, University of Texas, CIRAD, SBI, CTC, and consortia like the ICSB, SUCEST etc. However, very recently, there has been considerable involvement of several leading biotech companies such as Monsanto, DowAgro Sciences, Syngenta, DuPont, Amyris in countries such as Brazil, Australia, US and South Africa, aimed at commercial development of transgenic sugarcane, resulting in the emergence of new consortia, partnerships and acquisitions at various levels (Arruda, 2011).

Way forward

**Develop international sugarcane round tables of stakeholders to attract investments and partnerships in sugarcane research**

To meet the emerging challenges of sugarcane production and increase productivity rates more than in the past decades of achievements, investments in sugarcane research need to be doubled in the coming decades. Continued investment to meet production of new technologies to enhance sugarcane research can no longer be the sole responsibility of the public-sector, but requires greater participation from multiple stakeholders of sugar, energy, seed, biotech and pharmaceutical industries.

This calls for identification of institutional arrangements and organisational mechanisms to promote greater investment to support rapid innovation throughout the value chain of sugarcane.
feed stock production for sugar, energy, bio-fuels, bio-polymers and bio-pharmaceuticals. Such multi-stakeholder round tables should identify specific agendas for relevant sugarcane production, facilitating traditionally adversarial stakeholders and business competitors to work together towards a common objective. Mechanisms that stimulate participation and investment should be carefully designed and structured within the framework of the ISSCT to generate desirable incentives and results.

- Development of an ecosystem model of innovations
- enabling multiple stakeholder participation

In recent years, R&D challenges to develop new varieties and technologies with a quantum jump in productivity or other attributes have become increasingly specialised and complex. The cost, failure rates of varieties and technologies in farmer’s fields and the risks associated with it have substantially increased over time.

Regulatory frameworks for release of transgenic crops widened the gestation period and lag life for R&D investments in public as well as the private sector. Site specificity and productivity variability of sugarcane to climate, soil types, topography, latitude and altitude demand further investment in adaptive research for its wider adoption. Attracting and retaining young and talented people to sugarcane research continues to be difficult.

Against this background, it is important to look at a product development framework practised in most competitive industries such as information technology, telecommunications, consumer products and pharmaceuticals. Ecosystem innovations evolved in these industries are a systematic way of organising product development by preserving individual incentives, providing a degree of autonomy and maintain flexibility, while enabling complementary capabilities of diverse partners to be jointly leveraged.

Traditionally, new research on new processes or product development and marketing take place within an organisational boundary. In an open innovation system, organisations source and utilise external knowledge, ideas, intellectual assets and technologies, in addition to their own internal capabilities.

To enable participation of all, a decentralised web-based community platform is used for seeking solutions to a broad range of problems. Individuals, students, scientists, consumers, farmers, value chain partners, suppliers, universities, governments, competitors, vendors etc. from any part of world can provide ideas, knowledge, solutions or even participate in product or process or system development including resource and profit sharing.

Present day farmers increasingly demand integrated solutions for their multiple problems, rather than standardised individual varieties and services. At the same time, the necessary knowledge and capabilities to satisfy these no longer reside just in a few or large-scale organisations at national or international level.

Relevant knowledge and capabilities are abundant, widely dispersed and available in diverse industrial ecosystems. An open source model of innovation is a powerful tool to breakdown ‘silos’ and encourage the formation of networks that promote cross pollination of ideas.

This typically involves designing a broad-based multi-organisation network that brings together diverse germplasm resources, competencies, knowledge from different parts of the world to create a more complete solution for farmers and stimulating complementary investments by partners in R&D, production, distribution, delivery, market trade and training, extension and after sales service.

These processes can build an ecosystem relationship among partners resulting in collaborative advantage—a strategic asset growth and competitive success in the years ahead. Such creative partnerships will revitalise the R&D landscape to innovate, sustain, compete, expand and improve sugarcane production globally.
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EVOLUTION DE LA PRODUCTION DE CANNE A SUCRE - LA NÉCESSITÉ D'UN CHANGEMENT EN MATIERE DE RECHERCHE ET DE DÉVELOPPEMENT

Par

M.C. GOPINATHAN

E.I.D.Parry (India) Ltd,
Research & Development Centre, 145, Devanahalli Road, Off Old Road Madras,
Bangalore 560 049, INDE

gopinathan@threei.in

MOTS-CLÉS: Canne à Sucre, Recherche et Développement, Productivité, Innovation.

Résumé

La production de canne à sucre est en cours de changements structurels sans précédent, faisant face aux défis complexes de la croissance démographique, du développement économique, de la mondialisation du commerce, de la concurrence croissante des nouvelles exigences de bioénergie, du changement climatique et des impacts de divers stress biotiques et abiotiques. La demande mondiale de sucre devrait doubler d'ici le milieu de ce siècle. La canne à sucre comme matière première à usages multiples tels la production de sucre, d'énergie, d'alcool, de biocarburants, de biopolymères et de biopharmaceutiques connaîtra une demande accrue. La plupart de ces demandes et de cette croissance viendra vraisemblablement des systèmes agricoles tropicaux et subtropicaux d'Afrique, d'Asie et d'Amérique latine. Ces systèmes sont complexes, très hétérogènes, et sont dominés par des petits agriculteurs pauvres en ressources. Comme l'expansion de la superficie est limitée dans la plupart des pays producteurs de sucre, sauf au Brésil et dans certaines régions d'Afrique, l'augmentation de la production est susceptible de provenir de l'augmentation de la productivité agricole. Une analyse des données provenant des principaux pays producteurs de sucre et s'étalant sur 50 ans indique que, indépendamment de la croissance impressionnante de l'industrie sucrière pour les quatre dernières décennies, la croissance des rendements de canne a continué à stagner ou à baisser au cours des deux dernières décennies. La principale force motrice pour une
productivité accrue provient de la recherche agricole et des innovations à différents niveaux de la chaîne de valeur. Un grand nombre d'études ont fait état d'une contribution positive de la recherche agricole à la productivité. Toutefois, ces dernières années, un net ralentissement du financement public de la recherche et du développement a été évident. En outre, les programmes de recherche agricole des pays développés sont passés de la simple amélioration de la productivité à l'amélioration des attributs complexes mettant l'accent sur les systèmes de production (durabilité). L’investissement privé dans la recherche et le développement pour la canne à sucre est limité dans quelques pays comme le Brésil et l'Australie en raison de divers problèmes relatifs aux droits de propriété intellectuelle. Attirer et retenir des jeunes talents pour la recherche devient également difficile. Ces défis appellent un changement dans l'approche de la recherche sucrière. Le modèle de recherche proposé relatif à l'écosystème met l'accent sur un partenariat solide entre toutes les parties concernées, les innovateurs et les concepteurs afin de revitaliser et de mettre en synergie la recherche et le développement de la canne à sucre.

CAMBIANDO EL PANORAMA DE LA PRODUCCIÓN DE CAÑA DE AZÚCAR-NECESIDAD DE UN CAMBIO DE PARADIGMA EN LA INVESTIGACIÓN Y DESARROLLO DE LA CAÑA DE AZÚCAR

Por

M.C. GOPINATHAN

E.I.D. Parry (India) Ltd.,
Centro de Investigación y Desarrollo, 145, Devanahalli Road, Off Old Madras Road, Bangalore 560 049, India
gopinathan@threei.in

PALABRAS CLAVE: Caña de Azúcar, Investigación y Desarrollo, Productividad, Innovación.

Resumen

La producción de caña de azúcar está sufriendo cambios estructurales sin precedente, enfrentando retos complejos de crecimiento poblacional, desarrollo económico, globalización de las transacciones, competencia creciente de nuevas demandas bio energéticas, cambios climáticos e impactos de origen biótico y abiótico. Se espera que la demanda mundial de azúcar se duplique a mediados del presente siglo. La caña de azúcar como materia prima múltiple para la producción de azúcar, energía, alcohol, biocombustibles, bio polímeros y bio farmacéuticos sufrirá una mayor demanda. Las probabilidades de mayor crecimiento y demanda se darán en los sistemas agrícolas tropicales y subtropicales de los países en África, Asia y América Latina. En estos sistemas complejos y muy heterogéneos predominan pequeños productores con escasos recursos. Como el área de expansión está limitada en la mayor parte de los países productores de caña, excepto Brasil y algunas áreas de África, los incrementos en la producción deberán venir de incrementos en la productividad de las fincas. Un análisis de los datos de 50 años de las áreas con mayor producción de caña de azúcar, indica que independientemente del impresionante crecimiento de la industria azucarera en las últimas cuatro décadas, el incremento de la productividad se ha estancado e incluso ha disminuido durante los últimos veinte años. La fuerza impulsora para el incremento de la productividad viene de la investigación agrícola y las innovaciones en varios niveles de la cadena
de valor. Muchos estudios han reportado la contribución positiva de la investigación agrícola hacia la productividad. Sin embargo, en los últimos años, se ha sufrido una evidente reducción de fondos públicos para realizar investigación y desarrollo. Además, las agendas de investigación de los países en desarrollo han cambiado de la simple mejora en productividad a la mejora de atributos complejos enfocados a los sistemas de producción (sostenibilidad). La realización de investigación y desarrollo (I+D) con fondos privados está limitada a un menor número de países como Brasil y Australia, debido a problemas de derechos de propiedad intelectual. Además está el problema de atraer y retener talentos jóvenes que se interesen en la investigación. Estos retos llaman entonces a realizar un cambio en el paradigma con respecto a la investigación en caña de azúcar. En este trabajo se propone un modelo de investigación de ecosistema que enfatiza la fuerte colaboración de todas las partes interesadas, incluyendo a los innovadores y los creadores de ideas que revitalicen y ejerzan sinergia en el panorama de I+D de la caña de azúcar.

MUDANDO O CENÁRIO DA PRODUÇÃO DE CANA-DE-AÇÚCAR—NECESSIDADE DE UMA MUDANÇA DE PARADIGMA EM PESQUISA E DESENVOLVIMENTO DE CANA

Por
M.C. GOPINATHAN
E.I.D. Parry (India) Ltd., Centro de Pesquisa e Desenvolvimento, 145, Devanahalli Road, Off Old Madras Road, Bangalore 560 049, Índia
gopinathan@threei.in

PALAVRAS-CHAVE: Cana-de-Açúcar, Pesquisa e Desenvolvimento, Produtividade, Inovação.

Resumo
A PRODUÇÃO DE CANA-DE-AÇÚCAR está passando por mudanças estruturais inéditas, enfrentando complexos desafios de crescimento populacional, desenvolvimento econômico, globalização do comércio, crescentes demandas de bioenergia, mudanças climáticas e impactos causados por vários estresses bióticos e abióticos. Estima-se que a demanda mundial de açúcar duplicará até a metade deste século. A cana-de-açúcar, como uma matéria-prima multipla para produção de açúcar, energia, etanol, biocombustíveis, biopolímeros e biofarmacêuticos, sofrerá um aumento na demanda. A maior parte dessa demanda e do crescimento deve ocorrer nos sistemas agrícolas tropical e subtropical em países na África, Ásia, América Latina. Esses sistemas são complexos, altamente heterogêneos e dominados por produtores pequenos e com poucos recursos. Uma vez que a expansão de área é limitada na maior parte dos países produtores de cana, exceto no Brasil e em algumas partes da África, o aumento da produção deve originar-se do aumento da produtividade. Uma análise de dados de 50 anos das grandes áreas produtoras de cana indica que, independentemente do impressionante crescimento da indústria de açúcar nas últimas quatro décadas, o crescimento da produtividade tem se mantido estável ou diminuído nos últimos vinte anos. A principal força motriz de uma maior produtividade provém de inovações em pesquisa agrícola nos vários níveis da cadeia de valor. Um grande número de estudos tem oferecido uma contribuição positiva da pesquisa agrícola à produtividade. Entretanto, recentemente, observou-se uma diminuição acentuada de financiamento público para pesquisas e desenvolvimento em
agricultura. Além disso, os interesses das pesquisas agrícolas de países desenvolvidos voltaram-se da simples melhoria da produtividade para o aprimoramento de atributos complexos com foco em sistemas de produção (sustentabilidade). Investimentos privados em pesquisa e desenvolvimento em cana limitam-se a alguns países como o Brasil e a Austrália, devido a várias questões de direitos propriedade intelectual. Atrair e manter jovens talentos para a pesquisa têm também se tornado difícil. Esses desafios convidam a uma mudança de paradigma na abordagem em pesquisa em cana-de-açúcar. O modelo proposto de pesquisa de ecossistema enfatiza a forte parceria entre todos os interessados, inovadores e idealizadores para revitalizar e promover o sinergismo no cenário de pesquisa e desenvolvimento em cana-de-açúcar.
RESEARCH AND DEVELOPMENT ROADMAP FOR ENHANCING SUGARCANE PRODUCTION IN INDIA

By

S. SOLOMON

Indian Institute of Sugarcane Research, Lucknow-226 002 India
directoriisrlko@gmail.com

KEYWORDS: Sugarcane Production, Mechanisation, Input Use Efficiency, Cane Development.

Abstract

SUGARCANE OCCUPIES A PREDOMINANT position in the Indian Agricultural scenario on account of its wider adoption in agro-climatic conditions in the country. It has a significant role in the national economy, contributing over 1.0 per cent of national GDP. The Indian sugar industry plays a leading role in the global sugar market, being the world's second largest producer after Brazil, producing nearly 15 and 25 per cent of global sugar and sugarcane, respectively. In view of the food security concerns in the country and requirements of higher cane production from limited cane acreage (5.0 Mha), systematic research and development (R&D) efforts on sugarcane are being intensified for further increasing the yield and sugar recovery at the national level, which are currently around 68 t/ha and 10.30 per cent, respectively. Three basic issues that impede sugarcane cultivation are (1) Low levels of cane yield and sugar recovery, especially in sub-tropics (2) high cost of cane cultivation and (3) steep decline in factory productivity, have been addressed in Sugarvison-2030 of India. In order to meet sugar and energy requirements of the country, cane yield and sugar recovery must be augmented to 100 t/ha and 11.0 per cent, respectively from their current levels. Some of the major strategies being implemented at field level are cultivation of improved varieties, enhancing productivity of ratoons, nutrient use efficiency through rhizosphere engineering and INM technology, water use efficiency through micro-irrigation, land use efficiency through companion cropping, bio-intensive IPM and IDM, mechanisation of sugarcane farming, enhancing soil biological and nutritional dynamism through residue recycling, carbon sequestering through cropping system, prevention of sugar loss after harvest etc. At factory level, cane supplies, harvesting, transportation and payment systems have undergone computerisation which has greatly improved operational efficiency. These interventions and improvement at field and factory level may help in bringing the desired growth in production, productivity and sugar recovery in the country.

Introduction

Sugarcane in India is grown under two distinct agro-climatic conditions, tropical and sub-tropical belts. The tropical belt accounts for 40 per cent while the sub-tropical region constitutes around 60 per cent of the total cane area in the country.

The cane yields are lower in the sub-tropics due to short growing season, moisture stress, more pest and disease problems, floods and water-logging, and poor ratoon crops.

The average cane yield in the subtropical zone achieved so far at 59 t/ha is far below the average cane yield in the tropical zone (85 t/ha) and potential yield of sugarcane (474 t/ha) (Vision-2030, 2011). The current average sugarcane productivity in India is 68 t/ha/y.

The area under sugarcane from 1980–81 to 2011–12 has increased from 2.67 Mha to 5.08 Mha. There is hardly any possibility of additional area forthcoming under sugarcane, primarily
due to decreasing availability of arable land. Sugarcane is also facing stiff competition from food grain crops, oilseeds, pulses and other high value crops including vegetables in the share of area due to continuous rise in their prices.

In view of these considerations, it may not be possible to maintain the same growth rate of area and it may stabilise around 5.50 Mha by 2030 AD. It is apparent that, in future, the production target of sugarcane has to be met mainly by increasing the productivity and quality of the crop. The average productivity level needs a tremendous boost and it should touch 100 t/ha mark by 2030 AD.

Keeping in view the food security concerns in the country and the requirements of higher cane production from limited cane acreage, systematic research and development (R&D) efforts on sugarcane are required to be intensified for further increasing the yield levels at the national level, specifically in the sub-tropical region, and to increase the present trend of cane production to such a level that India becomes a sugarcane surplus country.

At national level, there are three basic issues that confront the sugar industry, and the corresponding strategies to address these issues for bringing the desired growth in area, productivity and recovery of sugar in the country (Solomon, 2011).

The following three key issues have been identified which need to be pursued.
1. Low levels of cane yield (68 t/ha/y)
2. High cost of cane cultivation (> US$1200/ha)
3. Decline in factory productivity (<9.5%)

**R & D strategies which have been formulated to overcome these issues and improve the cane and sugar productivity at national level**

**Efficient use of germplasm repository available in the country**

India has the world collection of sugarcane germplasm (4803 clones) and it is being maintained by the Sugarcane Breeding Institute, Coimbatore. It is imperative to tap this huge available genetic potential to break both sugar and yield barriers.

The research activities will be reoriented for evolving high sugar, high yielding and location specific sugarcane varieties with enhanced potential to withstand the various biotic and abiotic stresses. This could be achieved by utilising tissue culture tools and bio-technological innovations (Nair, 2011). The research aspects that need requisite focus are:

- Germplasm evaluation for high yield, high sugar, red rot resistance and better ratooning ability, and development of parental lines.
- Conventional breeding for desired traits using the developed parental lines.
- Marker assisted breeding and identification of molecular markers including ESTs for red rot resistance and other biotic stresses, thick cane with high sucrose accumulation and abiotic stresses.

**Intensification of seed program**

There has been consistent improvement in the cane and sugar yield potential of the varieties that were developed in the country during the past nine decades. The time required for multiplying the seed of a newly released variety is longer compared to other field crops. A three-tier seed program conceptualised and initiated by research institutions provides disease-free quality seed to growers and this needs to be intensified by all cane growing states of the country.

Recently, many states are distributing seed of improved sugarcane varieties through the National Agricultural Development Scheme (RKVY). All states need to have a sound and judicious seed program (such as seed villages) that must ensure that a potent variety is not being left out, and at the same time an inferior variety or rejected varieties are not popularised in the state.

A proper varietal composition with varieties of different maturity groups is also being recommended for ensuring high sugar recovery and the profitability of sugar mills. Some private
sector sugar mills have also made serious efforts in disseminating quality seed cane to growers but these efforts are not sufficient throughout the state. The efforts on the following aspects are needed in this regard:

- Breeder Seed Production and its fast multiplication.
- Faster seed cane multiplication through new technologies (STP/ bud chip/cane node/tissue culture)
- Development of efficient equipment for bulk scale treatment of seed cane.
- Development of a sound seed cane marketing and transport system.

**Abiotic stress management**

Sugarcane productivity in different states of the country varies depending on the agro-climatic conditions, crop management practices and biotic and abiotic stresses. The impact of these conditions is clearly visible on cane and sugar productivity. Based on cane productivity and sugar recovery, the sugarcane growing states in the country can be grouped into three zones (Table 1).

<table>
<thead>
<tr>
<th>Sugarcane productivity zones</th>
<th>Sugar recovery zones</th>
</tr>
</thead>
<tbody>
<tr>
<td>High (&gt;70 t/ha)</td>
<td>High (&gt;10%)</td>
</tr>
<tr>
<td>Tamil Nadu,</td>
<td>Maharashtra, Gujarath,</td>
</tr>
<tr>
<td>Maharashtra, Gujarath,</td>
<td></td>
</tr>
<tr>
<td>Karnataka, Andhr Pradesh</td>
<td>Karnataka</td>
</tr>
<tr>
<td>Medium (50–70 t/ha)</td>
<td>Medium (9–10%)</td>
</tr>
<tr>
<td>Uttar Pradesh,</td>
<td>Uttaranchal, Punjab,</td>
</tr>
<tr>
<td>Uttarakhand, Haryana,</td>
<td>Haryana, Bihar, Madhy</td>
</tr>
<tr>
<td>Punjab, Orissa, West</td>
<td>Pradesh, Rajasthan,</td>
</tr>
<tr>
<td>Bengal, Kerala</td>
<td>Andhr Pradesh</td>
</tr>
<tr>
<td>Low (&lt;50 t/ha)</td>
<td>Low (&lt;9%)</td>
</tr>
<tr>
<td>Bihar, Madhya Pradesh,</td>
<td>West Bengal, Assam,</td>
</tr>
<tr>
<td>Rajasthan, Assam</td>
<td>Kerala, Orissa</td>
</tr>
</tbody>
</table>

Productivity in different regions is conditioned by the agro-climatic factors. Both biotic and abiotic stresses cause loss in productivity. The stress factors across the country vary and technological interventions become necessary in every situation. Technology adoption in states of Tamil Nadu, Karnataka and Maharashrtra is quite high which is reflected in the productivity status. In the tropical region, sugarcane gets more or less ideal climatic conditions for its growth. It is cultivated with a better package of practices and higher irrigation levels.

The growing season is long with more equitable and favourable conditions without serious weather extremes. Moisture stress during the early part of the cane growth, mostly during March to June, is an important problem. Floods and water logging also occur and are the main problems for sugarcane cultivation in the region. The non-availability of water coupled with summer drought aggravates the stress effect and eventually lowers the crop yields in tropics.

The problem of short-term drought is common in rainfed agriculture which normally accounts for substantial loss in productivity. In sub-tropical regions, the extremes of climate are the characteristic feature. During April to June, the weather is very hot and dry and the temperatures are extremely high. December and January are the very cold months with temperature touching sub-zero levels in many places. The major portion of the zone i.e. the North-West zone, comprising the areas in Haryana, Punjab and Western U.P., has very low temperature in December-January which often causes frost. Because of extremes of weather, the active sugarcane growth is restricted to 4–5 months only. In eastern U.P, Bihar, and West Bengal, sugarcane suffers due to floods and water logging during the monsoon months.

Modification in cultural practices, development of stress-tolerant genotypes and use of PGRs are some of the options being considered to manage abiotic stress.
**Biotic stress management**

The biotic stress to the crop is mainly provided by insect-pest attack and the occurrence of diseases. Red rot and smut are important diseases affecting sugarcane production in the tropical region. Smut affects the cane crop particularly in the plateau region, while red rot has become a major threat in the coastal areas (Viswanathan and Rao, 2011).

Among the pests, early shoot borer, particularly in the late-planted crops, and woolly aphid in recent years are very serious in this region. Floods, water logging, and diseases such as red rot are the main problems for sugarcane cultivation in tropical regions. Several pests and diseases, particularly red rot and top borer and pyrilla, are also common and serious in sub-tropical regions. The following aspects need to be covered for biotic stress management research in sugarcane.

- Developing bio-intensive integrated management of red rot and borers.
- Evaluation of genetic resources (*Saccharum* germplasm) for sustainable sugar yield for biotic stresses.
- Screening of breeding population/selections against major diseases and insect pests.

**Improving cane yield and input-use efficiency in plant and ratoon crop**

The crop production research in the country pertains to development of suitable planting methods, plant population management, input (nutrient, water and energy) management, ratoon management, companion cropping, and the seed program. The major emphasis in crop production research has been on increasing production per unit area, increasing land use efficiency, and on improving ratoon cane productivity (50% area in sub-tropical India). The following strategies have been planned:

- Designing planting techniques aimed at efficient nutrient use
- Inclusion of legumes, recycling of crop residues, factory wastes and bio-fertilisers in sugarcane based cropping systems
- Improving nutrient use efficiency through elucidation of location and variety specific nutrient requirement of sugarcane based cropping systems
- Nutrient fixation and release in soil and uptake potential of cane genotypes with special reference to N, P, K, Ca, S, Zn, Fe, Mn
- Optimising shoot population through agro-techniques
- Designing suitable planting technique for multi-ratooning and improved stubble sprouting under low temperature conditions.

Sugar beet, with its in-built tolerance to saline conditions is also emerging as an alternative sugar crop, especially with respect to the current biofuel scenario. It can be grown as an inter-crop with sugarcane to increase net sugar and energy productivity per unit time and area. A lot more needs to be done so that this crop can be integrated into the existing cropping system as well as the milling stream.

**Water management**

Water requirement of the sugarcane crop is high in view of its long occupation in the field and to sustain the large biomass it produces. Sugarcane consumes 6.46% irrigation potential of the country whereas it occupies only 2.55% of the net cultivated area. The total consumptive use of water varies from 200 to 250 cm during the crop period. It has been estimated that about 250 tonnes of water are required to produce one tonne of cane. However, the actual requirement of water varies from place to place depending upon the climate, soil condition, crop duration and method of application.

The common method of irrigation followed for sugarcane is surface irrigation, either by flood or through furrows. However, the irrigation efficiency of surface irrigation is only 30–50% and there is considerable wastage of water.

Development of water use efficient technologies and micro-irrigation techniques become
relevant in this context, for conserving water and optimising its use. Keeping in view the reduced availability of water resources, there is an urgent and imperative need to enhance water use efficiency on all fronts, like improvement in methods of irrigation, water conservation and in the ways to utilise poor quality water.

**Cane development program**

For strengthening the development focus on these aspects, the cane development programs at every sugar mill level need to be made quite strong. Sound cane development programs have the capacity to better ensure protection of farm income through interventions in productivity and cane quality rather than price interventions, as is evident from the high cane productivities in TN.

The payment of cane price on time is another boosting factor to the farmers to continue cane cultivation with zeal, and it is responsibility of the mills to ensure it if they are desirous of building sound farm-factory relations with farmers’ interests intact.

**Mechanisation of sugarcane agriculture and post-harvest management**

Sugarcane is a labour intensive crop which remains in the field for more than a year. Being a long-duration crop of 12 months and its sowing spreading from October to May, 250 to 400 labour mandays per ha are required. Most of the cane operations are carried out manually and the use of machinery is limited only for field preparation.

The cost of cultivation of sugarcane has gone up significantly due to the increase in the cost of labour. Labour availability for major operations like harvest also has become scarce due to migration of labourers seeking urban employment. Cost of harvest is Rs. 300–400 per tonne (US$6-7/t cane) in the tropics which is almost 30% of the total cost of production.

The harvesters available at present are large sized and not suited for operations in our country where the size of the individual holdings is small. Smaller harvesters are being developed in Japan and are in operation in some of the South East Asian countries, which may prove successful under Indian conditions.

Mechanisation of planting operations and harvesting operations are the two main challenges which, if met with the collaboration of research institutions, government and the sugar mills, will make cane cultivation in India highly competitive. This will also give rise to a new kind of farm-factory relations in India.

Emphasis needs to be given to initiating multi-disciplinary and multi-stakeholder research for minimising post-harvest sucrose losses in cane as the cut to crush period is too long, resulting in considerable loss to millers and farmers. New valuable products need to be developed to utilise excess cane.

**Conclusion**

Sugarcane is a renewable source of sugar, biofuels, fibre, fertiliser and a myriad of products with ecological sustainability. Therefore, in future, cutting edge technologies will play a very important role in achieving greater sugar and sugarcane productivity.

While ongoing research efforts would require prioritisation to properly address these issues (low levels of cane yield, high cost of cane cultivation, decline in factor productivity), there is every need that the R&D challenges in sugarcane development are revisited afresh with a clear cut focus, renewed approach and newer tools, and that too in a multidisciplinary, collaborative and holistic manner. Increasing emphasis is given to strategic and anticipatory research, besides application of new technologies. Owing to increasing complexities in the modern crop production, it becomes imperative to utilise the competitive technologies involving biotechnology, bioinformatics, remote sensing etc.

Well defined packages including varietal scheduling, drought management, ratoon productivity, irrigation practices for improving water use efficiency, weed management, sucrose enhancement, environmental friendly use of sugar industry co-products/effluents, prevention of
post-harvest deterioration etc. will be given utmost importance in maximising the sugarcane crop production. On the development front, sound cane development programs in every sugar mill command area and the protection of farmers’ interests for ensuring them will ensure adequate farm income.

REFERENCES

LA FEUILLE DE ROUTE DE LA RECHERCHE ET DU DÉVELOPPEMENT POUR AMÉLIORER LA PRODUCTION DE CANNE A SUCRE EN INDE

Par
S. SOLOMON

Institut de recherches sucrières de l’Inde, Lucknow-226 002 Inde
directorisrlko@gmail.com

MOTS-CLÉS: Production De Canne à Sucre, Mécanisation, Utilisation Efficace d’Intrants, Développement de la Canne.

Résumé
LA CANNE À SUCRE occupe une place prépondérante dans le scénario agricole de l’Inde en raison de sa plus grande instauration dans les conditions agro-climatiques du pays. Au niveau de l'économie nationale, sa contribution est significative, s'élevant à plus de 1,0 pour cent du PIB. L'industrie sucrière joue un rôle de premier plan sur le marché sucrier international, l'Inde étant le deuxième producteur mondial, après le Brésil, avec une production de près de 15 et 25 pour cent de sucre et de cannes, respectivement. Compte tenu des problèmes de sécurité alimentaire du pays et des exigences d’une production accrue de cannes sur une superficie limitée (5,0 Mha), les efforts en matière de recherche systématique et de développement (R & D) sur la canne à sucre se sont intensifiés pour augmenter davantage le rendement et la récupération du sucre au niveau national, qui sont actuellement d'environ 68 t/ha et 10,30 pour cent, respectivement. Trois raisons fondamentales qui empêchent la culture de canne à sucre ont été abordées dans Sugarvision-2030 de l'Inde, notamment, (1) les faibles taux de rendement de canne et de récupération de sucre, en particulier dans les pays sous-tropicaux (2) le coût élevé de la culture de la canne et (3) la forte baisse de la productivité à l’usine. Afin de répondre aux besoins du pays en sucre et en énergie, le rendement de canne et la récupération de sucre doivent être augmentés à 100 t/ha et 11,0 pour cent respectivement par rapport aux niveaux actuels. Quelques stratégies majeures qui ont été mises en œuvre au niveau des champs sont : la culture de variétés plus performantes ; l'amélioration de la productivité des repousses ; la gestion intégrée des intrants et leur meilleure utilisation en rendant la rhizosphère plus efficace; l'utilisation judicieux de l'eau par le biais de la micro-irrigation ; l'utilisation efficace des terres avec des cultures intercalaires ; la lutte biologique intégrée des ravageurs et des maladies ; la mécanisation des pratiques culturelles ; le rehaussement du dynamisme biologique et nutritionnel du sol à travers le recyclage des résidus ; la séquestration du carbone par le biais des méthodes de culture ; la prévention de la perte de sucre après la récolte, etc. Au niveau de l'usine, l'approvisionnement en cannes, la récolte, le transport et les systèmes de
El cultivo de caña de azúcar ocupa una posición predominante en el escenario agrícola de India debido a su amplia adaptabilidad a las condiciones agro-climáticas del país. Tiene un rol significativo en la economía nacional contribuyendo con más del 1.0 por ciento al PIB. La industria azucarera india juega un rol importante en el mercado del azúcar, siendo el segundo productor mundial después de Brasil, produciendo aproximadamente el 15 por ciento del azúcar y el 25 por ciento de la caña a nivel mundial. Debido a la preocupación que existe por la seguridad alimentaria en el país y a los requerimientos de mayor producción de caña en un área limitada (5.0 Mha), se han intensificado los esfuerzos sistemáticos en investigación y desarrollo (I+D) en caña de azúcar para aumentar aún más la productividad y la recuperación de azúcar a nivel nacional, que actualmente están alrededor de 68 t/ha y 10.30 por ciento, respectivamente. Los tres factores que obstaculizan el cultivo de la caña de azúcar y que han sido tratados en Sugarvision-2030 de India son: (1) bajos niveles de productividad de la caña y de recuperación del azúcar, especialmente en las áreas subtropicales, (2) alto costo del cultivo y (3) caída estrepitosa de la productividad de las fábricas. Para cumplir con la demanda de azúcar y energía del país, la productividad de caña y el porcentaje de recuperación de azúcar deben incrementar de los niveles actuales a 100 t/ha y 11.0 por ciento, respectivamente. Algunas de las estrategias principales que están siendo implementadas en campo son: cultivo de variedades mejoradas, mejoramiento de la productividad de las socas, eficiencia en el uso de nutrientes a través del uso de ingeniería de rizósfera y Manejo Integrado de Nutrientes (MIN), eficiencia en el uso del agua a través de micro-riego, eficiencia en el uso de la tierra a través de la asociación de cultivos, estrategias bio intensivas en Manejo Integrado de Plagas (MIP) y Manejo Integrado de Enfermedades (MIE), mecanización de las labores de cultivo, mejoramiento de la dinámica biológica y nutricional a través del reciclaje de residuos, secuestro de carbono a través de sistema de cultivo, prevención de pérdidas de azúcar post-cosecha, etc. A nivel de fábrica, se han automatizado los sistemas de suministro de la caña, cosecha, transporte y pago, lo que ha aumentado significativamente la eficiencia operativa. Estas intervenciones y las mejoras aplicadas tanto en campo con en fábrica pueden ayudar a alcanzar el incremento deseado en producción, productividad y recuperación de azúcar en el país.
ROTEIRO DE PESQUISA E DESENVOLVIMENTO PARA MELHORAR
A PRODUÇÃO DE CANA-DE-AÇÚCAR NA ÍNDIA

Por

S. SOLOMON

Instituto Indiano de Pesquisas em Cana-de-Açúcar, Lucknow-226 002 Índia
directoriisrlko@gmail.com

PALAVRAS-CHAVE: Produção de Cana-de-Açúcar,
Mecanização, Eficiência de Uso de Insumos,
Desenvolvimento de Cana.

Resumo

A CANA-DE-AÇÚCAR ocupa uma posição predominante no cenário agrícola indiano devido à sua extensa adoção nas condições agroclimáticas do país. Ela possui um papel significativo na economia nacional, contribuindo com mais de 1,0 por cento do PIB doméstico. A indústria de açúcar indiana desempenha um papel fundamental no mercado mundial de açúcar, sendo o segundo maior produtor logo após o Brasil, produzindo cerca de 15 a 25 por cento do açúcar de cana do mundo, respectivamente. Em vista das preocupações acerca da segurança alimentar no país e das exigências de maior produção de cana em áreas limitadas (5,0 Mha), esforços sistemáticos de pesquisa e desenvolvimento em cana estão sendo intensificados para aumentar a produtividade e a recuperação de açúcar em nível nacional, que é atualmente de cerca de 68 t/há e 10,30 por cento, respectivamente. Três questões básicas que impedem o cultivo de cana-de-açúcar são (1) os baixos níveis de produtividade e recuperação de açúcar, especialmente em áreas subtropicais, (2) o alto custo de cultivo de cana, e (3) o declínio acentuado da produtividade da fábrica, foram tratados no evento Sugarvision-2030 na Índia. Para atender às exigências de açúcar e energia do país, os níveis atuais de produtividade de cana e recuperação de açúcar devem aumentar para 100 t/ha e 11%, respectivamente. Algumas das principais estratégias sendo implementadas no campo são o cultivo de variedades melhoradas, melhoria da produtividade das soqueiras, eficiência de uso de nutrientes por meio de engenharia de rizosfera e tecnologia INM, eficiência de uso hídrico por meio de micro irrigação, eficiência de uso de terra por meio de cultivo cooperado, IPM e IDM bio-intensivos, mecanização do plantio de cana, melhoria do dinamismo biológico e nutricional do solo por meio de reciclagem de resíduos, sequestro de carbono pelo sistema de cultivo, prevenção de perdas de açúcar após a colheita, etc. Na fábrica, sistemas de fornecimento, colheita, transporte e pagamento de cana foram informatizados, aumentando muito a eficiência operacional. Essas intervenções e as melhorias no campo e na fábrica podem ajudar a alcançar o crescimento desejado na produção, na produtividade e na recuperação de açúcar no país.
THE EFFECT OF KNOWLEDGE MANAGEMENT AS A TECHNOLOGY TRANSFER TOOL ON THE RELATIONSHIP BETWEEN INTELLECTUAL CAPITAL AND BUSINESS PERFORMANCE: A CASE STUDY OF THE IRAN SUGARCANE INDUSTRY

By

H. VALIEIDY¹ and T. TAHA²

¹Iranian Society of Sugarcane Technologists, Iran
²University of Malaya (UM), Malaysia

hvalieidy@yahoo.com

KEYWORDS: Knowledge Management, Technology Transfer, Intellectual Capital, Business Performance.

Abstract

In this study, we hypothesise that knowledge management systems as a technology transfer tool are a facility for developing knowledge in a company and that this system affects the correlation between intellectual capital and business performance. To test this hypothesis, we studied the effect of knowledge management on business performance as a moderating variable. Therefore, we attempt to explain the relationship between intellectual capital and business performance regarding knowledge management. It was found that the knowledge management system moderates the relationship between intellectual capital and business performance. We also found a positive correlation between three dimension of intellectual capital and business performance. Despite a positive correlation between intellectual capital and business performance, when we controlled the effect of knowledge management, we observed that the correlation was less than before. This indicates a significant effect of knowledge management on intellectual capital and business performance. It is observed by correlation analysis that KM as a moderated variable, has a positive effect on the business performance, and we show that the relationship between IC and BP is positively moderated by KM.

Introduction

In this study, we hypothesise that there is a relationship between the management of intellectual capital and business performance. To test this hypothesis, we consider the role of knowledge management in adjusting this relationship. The management of intellectual capital includes management style, internal processes, customer relationship, employee satisfaction and knowledge management. (On the basis of previous studies on intellectual capital (Liebowitz and Suen, 2000), the role of human capital is more important than others (structural capital and customer capital).) We surveyed 10 Iranian firms associated with sugarcane. The sample was selected on the basis of organisational field and social perspective. Nowadays, little attention is paid to intellectual assets in most Iranian firms. In spite of some limitations in intellectual asset management, this study can be helpful in altering the management perspective about intellectual asset and knowledge management.

Relevant literature

The money that enterprises spend on human resources has traditionally been reported in the accounts as a cost, rather than as an investment. This has even been the case in firms and organisations that rely heavily on the knowledge and skills (intellectual capital) of their staff to
generate earnings and growth and to improve efficiency and productivity (Brennan and Connell, 2000). Petty and Guthrie (2000) divided intellectual capital into 3 dimensions, and these dimensions and sub-dimension of intellectual assets are shown in Table 1.

**Table 1**—Modified intangible assets monitor (Guthrie and Petty, 2000).

<table>
<thead>
<tr>
<th>Intellectual assets</th>
<th>Dimension</th>
<th>Sub-dimension</th>
</tr>
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<tbody>
<tr>
<td>Internal:</td>
<td>Intellectual property</td>
<td>Patents</td>
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<tr>
<td>organisational (structural) capital</td>
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<td>Copyrights</td>
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<td></td>
<td>Infrastructure assets</td>
<td>Trademarks</td>
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<td>Management philosophy</td>
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<td>Corporate culture</td>
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<td>Information systems</td>
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<td>Networking systems</td>
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<td></td>
<td></td>
<td>Financial relations</td>
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<tr>
<td>External: customer (relational) capital</td>
<td>Brands</td>
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<td>Customer loyalty</td>
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<td>Company names</td>
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<td>Distribution channels</td>
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<td>Business collaborations</td>
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<td>Licensing agreements</td>
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<td>Favourable contracts</td>
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<td>Franchising agreements</td>
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<td>Employee competence: human capital</td>
<td>Know-how</td>
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<td>Education</td>
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<td>Vocational qualification</td>
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<td>Work-related knowledge</td>
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<td></td>
<td></td>
<td>Work-related competencies</td>
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<td></td>
<td></td>
<td>Entrepreneurial spirit, innovativeness, proactive and reactive abilities, changeability</td>
</tr>
</tbody>
</table>

In the results, we summarise all of the criteria and sub-criteria of intellectual capital on the basis of this literature review, and in Table 2 we divide intellectual capital into three sub-criteria namely human capital, structural capital and customer capital.

**Table 2**—Sub-dimension of intellectual capital.

<table>
<thead>
<tr>
<th>Intellectual capital</th>
<th>Human capital</th>
<th>Structural capital</th>
<th>Customer capital</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-Knowledge, skills and abilities of employees</td>
<td>-Processes</td>
<td>-Strength and loyalty of customer relations</td>
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<tr>
<td></td>
<td>-Combined human ability to solve business problems</td>
<td>-Trademarks</td>
<td>-Customer satisfaction</td>
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<td></td>
<td>-Inherent in people, not owned by the organisation</td>
<td>-Information systems</td>
<td>-Repeat business</td>
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<td></td>
<td>-Proprietary databases</td>
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</table>

**Knowledge management**

Knowledge management systems (KMS) are becoming increasingly important to organisations, both for their strategic potential and as a crucial resource (Liebowitz and Suen, 2000).

Consequently several organisations have established these systems in order to leverage the combined knowledge of individual employees – their intellectual capital – and disseminate this amalgam to promote organisational learning in order to increase decision making effectiveness and ultimately competitive positioning.

Organisations are increasingly adopting the resource-based view of knowledge which holds that the accumulation of their employees’ knowledge is a primary asset and a resource to be managed like other organisational assets (Wenger, 2004).
Performance measurement

On the basis of historical study, we divide business performance in to financial and non-financial indicators that are summarised in Table 3.

<table>
<thead>
<tr>
<th>Table 3—Business performance criteria.</th>
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<tr>
<td><strong>Business performance</strong></td>
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<tr>
<td>Financial measures</td>
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<tr>
<td>Profit</td>
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<td>Profit growth</td>
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<td>Sales growth</td>
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<td>After-tax return on assets</td>
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<td>Share prices</td>
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<td>After-tax return on sales</td>
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<tr>
<td>Industry leadership</td>
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<td></td>
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<tr>
<td>Non-financial measures</td>
</tr>
<tr>
<td>Future outlook</td>
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<tr>
<td>Overall response to competition</td>
</tr>
<tr>
<td>Success rate in new product</td>
</tr>
<tr>
<td>Lauches</td>
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<tr>
<td>Overall business performance</td>
</tr>
<tr>
<td>Success</td>
</tr>
</tbody>
</table>

Research methodology

In this study, ten firms were selected and a questionnaire was sent to 12 expert people from a range of disciplines within each (see Table 4). In all 120 questionnaires were sent and 80 were returned from 10 firms giving a response rate of 66.6%. The results from each firm was the average of all respondents from that firm.

<table>
<thead>
<tr>
<th>Table 4—Disciplines represented sampling distribution.</th>
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<tbody>
<tr>
<td><strong>Field</strong></td>
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<tr>
<td>Agriculture</td>
</tr>
<tr>
<td>Manufacturing</td>
</tr>
<tr>
<td>Logistics</td>
</tr>
<tr>
<td>Planning and engineering</td>
</tr>
</tbody>
</table>

To collect operational data, we examined a range of documents for each firm, including the Iranian National and Productivity Excellence award’s statement, financial data, social perspective etc.

Theoretical framework

The model used in this study was developed following a review of the literature (Stewart, 1999; Tayles et al., 2007; Saudah et al., 2006; Bontis 2001; Rao and Osei-Bryson 2007; Amaratunga et al., 2001; Chen and Chen, 2005; Nonaka 1994).

As the three intellectual capitals (IC) are complementary, intellectual capital can only create value by combining each of them (Rao and Osei-Bryson, 2007). Therefore, the final business performance (BP) of an organisation is influenced by the interactions between the three dimensions of intellectual capital. Dzinkowski (2000) and Edvinsson (2000) stressed that human capital (HC) was a cornerstone and influential factor in intellectual capital (Liebowitz and Suen, 2000). Thus IC with sub-criteria is an independent variable that affects the BP (as dependent variable). Knowledge management (KM) is a moderated variable that affects the relationship between IC and BP (Figure 1).

Findings and discussion

Correlation analysis

Table 5 illustrates the correlation between the independent variables (human capital, structural capital, customer capital) and (business performance). In this table it can be seen that there is a positive correlation between human capital (HC) and business performance (BP) (0.807**), structural capital (SC) and BP (0.581**) and customer capital (CC) and BP (0.76**). There is also a positive relationship between HC and SC (0.454*) and HC and CC (0.73**).
Table 5—Correlation matrix of measured dimensions.

<table>
<thead>
<tr>
<th></th>
<th>HC</th>
<th>SC</th>
<th>CC</th>
<th>KM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human capital</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Structural capital</td>
<td>.454(*)</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Customer capital</td>
<td>.730(**)</td>
<td>.510(**)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Knowledge management</td>
<td>.769(**)</td>
<td>.481(**)</td>
<td>.711(**)</td>
<td>1</td>
</tr>
<tr>
<td>Business performance</td>
<td>.807(**)</td>
<td>.581(**)</td>
<td>.760(**)</td>
<td>.893(**)</td>
</tr>
</tbody>
</table>

* P< 0.05 ** P< 0.01

Regarding Table 5, customer capital is more positively correlated than structural capital with BP; on the other hand, human capital has the most positive correlation with BP. Also there is a positive correlation among the 3 dimensions of intellectual capital, especially the correlation of human capital and customer capital of 0.73**.

Table 6—Correlation matrix of measured dimensions.

<table>
<thead>
<tr>
<th></th>
<th>HC</th>
<th>SC</th>
<th>CC</th>
<th>BP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge management</td>
<td>.769(**)</td>
<td>.481(**)</td>
<td>.711(**)</td>
<td>.893(**)</td>
</tr>
</tbody>
</table>

* P< 0.05 ** P< 0.01

Table 6 shows a positive and direct correlation between knowledge management and business performance. Moreover, there is also a positive correlation between the 3 dimensions of intellectual capital and knowledge management, and a strong correlation between human capital and knowledge management of 0.769**.

Controlling KM’s effects

On the basis of the main hypothesis, we assumed KM’s positive effect on the relationship between IC and BP, we will need to control the effect of KM as a moderated variable on the BP as an independent variable if we want to test this hypothesis.
Table 7—Correlation matrix of measured dimensions.

<table>
<thead>
<tr>
<th>Control variables</th>
<th>HC</th>
<th>SC</th>
<th>CC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge management</td>
<td>Human capital</td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Structural capital</td>
<td>.151</td>
<td>1.000</td>
</tr>
<tr>
<td></td>
<td>Customer capital</td>
<td>.407(*)</td>
<td>.272</td>
</tr>
<tr>
<td></td>
<td>Business performance</td>
<td>.418(*)</td>
<td>.384(*)</td>
</tr>
</tbody>
</table>

* P< 0.05  ** P< 0.01

Therefore, we control KM’s effect in this study to see the correlations of IC’s criteria and business performance. Thus, it is considered the effect of independent variable (HC, SC, CC) on the business performance has been become less than before. Therefore, we can claim ‘relationship between Intellectual capital and organisational performance is positively moderated by the Knowledge Management System’ (see Table 7).

Controlling IC sub-criteria’s effect

We want to analyse the effect of sub-criteria of intellectual capital on the business performance, so we controlled the effect of HC, SC and CC, then studied correlation between IC and BP.

Table 8—Correlation matrix of measured dimensions.

<table>
<thead>
<tr>
<th>Control variables</th>
<th>SC</th>
<th>CC</th>
<th>IC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human capital</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Human capital</td>
<td>1.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Structural capital</td>
<td>.293</td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td>Customer capital</td>
<td>.546</td>
<td>.442</td>
<td>1.000</td>
</tr>
<tr>
<td>Business performance</td>
<td>.408</td>
<td>.422</td>
<td>.711</td>
</tr>
<tr>
<td>Structural capital</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Human capital</td>
<td>1.000</td>
<td></td>
<td>IC</td>
</tr>
<tr>
<td>Structural capital</td>
<td>.650</td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td>Customer capital</td>
<td>.910</td>
<td>.703</td>
<td>1.000</td>
</tr>
<tr>
<td>Business performance</td>
<td>.749</td>
<td>.662</td>
<td>.857</td>
</tr>
<tr>
<td>Customer capital</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Human capital</td>
<td>1.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Structural capital</td>
<td>.140</td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td>Customer capital</td>
<td>.819</td>
<td>.391</td>
<td>1.000</td>
</tr>
<tr>
<td>Business performance</td>
<td>.568</td>
<td>.346</td>
<td>.769</td>
</tr>
</tbody>
</table>

* P< 0.05  ** P< 0.01

Corresponding to Table 8 there is significant correlation between IC and BP. When we controlled the effect of IC, we saw that the effect of IC on the BP will be less than before. With controlling HC, correlation of IC and BP will be less but not as the control of HC. As a result, the effect of HC on the BP is the most positive.

Functional data analysis

In this part, we studied the correlation between operational data such as Iranian National and Productivity Excellence award (INPE), capital and number of personnel with prime variables such as KM, IC and BP.
Table 9—Correlation matrix of measured dimensions.

<table>
<thead>
<tr>
<th></th>
<th># of personnel</th>
<th>INPE Award</th>
<th>Capital</th>
<th>KM</th>
<th>BP</th>
<th>IC</th>
</tr>
</thead>
<tbody>
<tr>
<td># of personnel</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>INPE Award</td>
<td>.684(**)</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capital</td>
<td>.691(**)</td>
<td>.809(**)</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knowledge management</td>
<td>.556(**)</td>
<td>.792(**)</td>
<td>.725(**)</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Business Performance</td>
<td>.645(**)</td>
<td>.832(**)</td>
<td>.831(**)</td>
<td>.85(**)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Intellectual Capital</td>
<td>.579(**)</td>
<td>.847(**)</td>
<td>.859(**)</td>
<td>.853(**)</td>
<td>.907(**)</td>
<td>1</td>
</tr>
</tbody>
</table>

* P< 0.05    ** P< 0.01

Table 9 shows significant correlation between INPE awards with IC (0.847**), with KM (0.792**) and with BP (0.832**). Also, there is positive correlation between capital and KM (.725**) and capital with IC (.859**).

In general, we can conclude: firms that work well in KM and IC get a good mark in INPE awards; also firms that have high capital are better than other firms that have less capital.

Finally, we see the correlation between number of personnel with IC, KM and INPE awards. This shows the importance of a high social perspective organisation concerned with knowledge management and intellectual capital. Also this organisation has better performance than other organisations.

Conclusion

In this paper, we have examined the hypothesis that ‘the relationship between intellectual capital and organisational performance is positively moderated by the Knowledge Management System’. We have offered findings based on sugarcane industrial Iranian firms.

Findings suggest that the level of business performance in these organisations is associated with knowledge management practices, concern to IC, and the social perspective. IC has a direct effect on the business performance but KM is a moderated variable.

Finding out that KM is a moderated variable has a positive effect on the business performance and we showed that relationship between IC and BP is positively moderated by KM. Also we analysed the correlation between sub-dimension of IC and BP, so we find positive relation between these variables. In addition, there is a positive correlation between level of IC with BP and with them.

The result shows that human capital has a significant influence on structural capital and relational capital. Therefore, we suggest that enterprises should make more investment in this area, for example, by developing staff education, enhancing the training process, and management of their knowledge.

REFERENCES


L'EFFET DE LA GESTION DES CONNAISSANCES COMME OUTIL DE TRANSFERT DE TECHNOLOGIE SUR LA RELATION ENTRE LE CAPITAL INTELLECTUEL ET LA PERFORMANCE DE L'ENTREPRISE: UNE ÉTUDE DE CAS DE L'INDUSTRIE SUCRIERE IRANIENNE

Par
H. VALIEIDY1 et T. TAHA2

1Association des technologistes sucriers iraniens, Iran
2Université de Malaya (UM), Malaisie
hvalieidy@yahoo.com

MOTS-CLÉS: Gestion des Connaissances,
Transfert de Technologie,
Capital Intellectuel,
Performance de l’Entreprise.

Résumé
Dans cette étude, nous émettons l'hypothèse que les systèmes de gestion des connaissances, comme outil de transfert de technologie, sont un mécanisme pour le développement des connaissances dans une entreprise et que ce système influe sur la corrélation entre le capital intellectuel et la performance de l’entreprise. Pour tester cette hypothèse, nous avons étudié l'effet de la gestion des connaissances sur la performance de l'entreprise en tant que variable modératrice. Par conséquent, nous essayons d'expliquer la relation entre le capital intellectuel et la performance de l’entreprise en matière de gestion des connaissances. Il a été constaté que le système de gestion des connaissances modère la relation entre le capital intellectuel et la performance de l’entreprise. Nous avons également constaté une corrélation positive entre trois aspects du capital intellectuel et la performance de l’entreprise. Malgré une corrélation positive entre le capital intellectuel et la
EL EFECTO DE LA GESTIÓN DEL CONOCIMIENTO COMO HERRAMIENTA DE TRANSFERENCIA DE TECNOLOGÍA EN LA RELACIÓN ENTRE EL CAPITAL INTELECTUAL Y EVOLUCIÓN DE LOS NEGOCIOS: UN ESTUDIO DE CASO DE LA INDUSTRIA AZUCARERA DE IRAN

Por

H. VALIEIDY¹ y T. TAHA²

¹Asociación de Técnicos Azucareros de Irán, Irán
²Universidad Malaya (UM), Malasia

hvalieidy@yahoo.com

PALABRAS CLAVE: Gestión del Conocimiento, Transferencia de Tecnología, Capital Intelectual, Desempeño Empresarial o del Negocio.

Abstract
EN ESTE ESTUDIO se manejó la hipótesis que cuando los sistemas de gestión del conocimiento son usados como una herramienta de transferencia de tecnología ayudan en el desarrollo del conocimiento en una empresa y afectan la correlación existente entre el capital intelectual y el desempeño del negocio. Para probar esta hipótesis, se estudió el efecto de la gestión del conocimiento en el desempeño del negocio como una variable moderadora. Entonces se intentó explicar la relación existente entre el capital intelectual y el rendimiento empresarial con respecto a la gestión del conocimiento. Se determinó que el sistema de gestión del conocimiento modera la relación existente entre el capital intelectual y el desempeño del negocio. También se encontró una correlación positiva entre las tres dimensiones del capital intelectual y el desempeño. Aunque se determinó una correlación positiva entre el capital intelectual y el desempeño, cuando se controló el efecto de la gestión del conocimiento, se observó que la correlación era menor que la determinada anteriormente. Esto indica que hay un efecto significativo de la gestión del conocimiento sobre el capital intelectual y el desempeño del negocio. Se observó por un análisis de correlación que GC, una variable moderada, tiene un efecto positivo en el desempeño del negocio y se muestra que la relación entre CI y DN es positivamente moderada por GM.
O EFEITO DO GERENCIAMENTO DE CONHECIMENTO COMO FERRAMENTA DE TRANSFERÊNCIA TECNOLÓGICA NA RELAÇÃO ENTRE CAPITAL INTELECTUAL E DESEMPENHO COMERCIAL: UM ESUDO DE CASO DA INDÚSTRIA CANAVIEIRA DO IRÁ

Por

H. VALIEIDY¹ e T. TAHA²

¹Sociedade Iraniana dos Técnicos em Cana-de-Açúcar, Irã
²University of Malaya (UM), Malásia

hvalieidy@yahoo.com

PALAVRAS-CHAVE: Gerenciamento de Conhecimento, Transferência de Tecnologia, Capital Intelectual, Desempenho Comercial.

Resumo

NESTE ESTUDO, formulamos a hipótese de que sistemas de gerenciamento do conhecimento como ferramenta de transferência de tecnologia são uma conveniência para desenvolver o conhecimento em uma empresa e que esse sistema afeta a correlação entre o capital intelectual e o desempenho comercial. Para testar esse hipótese, estudamos o efeito do gerenciamento de conhecimento no desempenho comercial com uma variável moderadora. Assim, tentamos explicar a relação entre o capital intelectual e o desempenho comercial com relação ao gerenciamento de conhecimento. Descobriu-se que o sistema de gerenciamento de conhecimento modera a relação entre o capital intelectual e o desempenho comercial. Também foi encontrada uma correlação positiva entre três dimensões do capital intelectual e do desempenho comercial. Apesar da correlação positiva entre o capital intelectual e o desempenho comercial, quando controlamos o efeito do gerenciamento de conhecimento, notamos que a correção era menor do que anteriormente. Isso indica que existe um efeito significativo do gerenciamento do conhecimento no capital intelectual e no desempenho comercial. Observou-se por uma análise de correlação que a KM como variável moderada possui um efeito positivo no desempenho comercial e demonstrou-se que a relação entre IC e BP é positivamente moderada pela KM.
THE ACP SUGARCANE RESEARCH AND DEVELOPMENT PROGRAM: A TANGIBLE EXAMPLE OF SUCCESSFUL MULTIDISCIPLINARY APPROACH TO ADVANCE KNOWLEDGE ON SUGARCANE

By

J.C. AUTREY\textsuperscript{1}, D.M. HOGARTH\textsuperscript{2} and G.R. LIONNET\textsuperscript{2}

\textsuperscript{1} Consultant, Mauritius
\textsuperscript{2} Consultant, Australia

jcautrey@intnet.mu

KEYWORDS: Research, Development, Collaboration, Sustainability, Competitiveness.

Abstract

Collaborative efforts in sugarcane research and development were felt to be of vital importance by the researchers of the African, Caribbean and Pacific (ACP) states, members of the Sugar Protocol of the Lomé Convention between the European Union and the ACP States. Twelve priority areas were identified in 1999 and research projects designed to increase productivity, profitability and sustainability as well as the competitiveness of the respective sugar industries of the ACP were developed. Funding of the order of 13m Euro from the 9th European Development Fund (EDF) became available in 2007 through an agreement between the EU and the ACP Secretariat. The 13 selected projects were grouped along three main themes namely: Development of new highly productive sugarcane varieties, Reduction of cost of production while reducing negative environmental externalities, and Value addition through resort to co-products. Implementation was initiated in 2010 in research centres in Mauritius, Fiji, Barbados, Jamaica and Swaziland. The program encompassed 14 ACP countries. It has a Coordinating Unit located in Brussels. It is administered by a Steering Committee and its science is overseen by a Scientific Advisory Group composed of three experienced sugarcane researchers. The projects are well underway in spite of various difficulties at the initial stage. A Mid-Term Review Workshop was held in October 2012 and the program will be completed in 2014. Substantial progress has been achieved in some of the projects and by the end of the program most projects would have been completed and those which have longer time lines will be pursued by the respective research centres involved. This program is a tangible example of collaborative research to advance knowledge on sugarcane and to exploit more substantially than at present, the sugar cane biomass. A second program is under preparation.

Introduction

At a Workshop held in Barbados from 12 to 16 July 1999, the Directors of the sugarcane research centres of the African, Caribbean and Pacific countries (ACP), members of the Sugar Protocol of the Lomé Convention between the ACP and the European Union (EU) discussed research priorities and agreed on a collaborative program in the presence of representatives of the ACP Secretariat and officials of the European Union (EU) from Brussels.

The Bridgetown Statement on Intra-ACP Cooperation on Sugar was formulated and adopted as follows:

2030
‘To increase productivity, profitability and sustainability of the respective sugar industries of the ACP countries by surmounting common challenges through institutional collaboration in R&D and information exchange.’

The priority areas for collaboration were identified as crop improvement, crop protection, crop management, environment and natural resource management, sugar technology and sugar engineering, economics and technology transfer, information technology, human resource development, international collaboration e.g. with non-ACP research institutions, and intellectual property rights. priority projects were to be developed in crop improvement, crop management, crop protection, biotechnology, germplasm exchange, resource management, environment, cane processing and energy use.

A scientific five-member Committee was elected to implement the decisions. It was composed initially of L.J.C Autrey, Chairman (Mauritius), M. Clowes, Secretary (Swaziland), J. Gawander (Fiji), J. Jaddoo (Jamaica) and C. Kelly (St Kitts). Later Musa Dlamini replaced M. Clowes and H. Davis from Guyana replaced C. Kelly. The Committee set to work and, by 2003, 14 project proposals had been prepared as follows: Barbados (1), Fiji (2), Jamaica (1), Swaziland (1) and Mauritius (9).

It was only in May 2006 at the 83rd session of the ACP Council of Ministers in Papua New Guinea that funding was made available and the elements of agreement were: ‘Sugar: increase the amount allocated to the financing of a sugar research project to underpin measures to accompany reform in countries covered by the Sugar Protocol to 13 million Euros.’ The ACP Ambassadors from the Sugar Protocol countries in Brussels played a considerable role through their Sugar Committee to lobby the EU for funding.

Sixteen research project proposals were prepared according to the Project Cycle Management Guidelines of EU and submitted to the EU. Through discussions between ACP Secretariat and EU directorates for development and aid (DG DEV and AIDCO), it was agreed that the projects would be evaluated by a three-member international team of consultants whose Terms of Reference were:

- Identify the strategic framework and priorities for ACP sugarcane research,
- Define focus of program,
- Review projects and prioritise them,
- Include a component of structural strengthening,
- Check consistency with EU policies and other research initiatives,
- Define most appropriate structure to manage the program,
- Prepare a strategic options document,
- Elaborate on the agreed implementation option and prepare a draft financing proposal.

The consultants visited the countries from which projects had originated, had in-depth discussions with principal investigators and stakeholders, and advised the researchers on various criteria contained in EU regulations that had to be adhered to and on ways to improve their proposals.

Based on 15 re-worked research proposals, the consultancy team recommended that 11 proposals be financed based on their relevance, technical feasibility, economic and financial feasibility, institutional and managerial feasibility, and sustainability. A further two proposals were later approved through a mechanism of competitive submissions. Important elements of the program were that all ACP sugar producing countries should benefit from it and that it should contain a comprehensive capacity building component. A financing agreement was signed between the EU and the ACP states in late 2007 with an envelope of 13m Euros. The modalities of implementation of the program were defined.
Contracts and grants were to be awarded and implemented in accordance with general regulations for works, supply and service contracts adopted by the ACP-EC Council of Ministers and supplemented by rules governing the 9th European Development Fund (EDF) from which the financial resources had been made available. The overall program goal was defined as ‘To enhance the capability of the sugar industries in ACP countries to make the transition to (and exploit the opportunities of) a more open and less protected sugar market.’

It should be emphasised that, concurrently with the reform of the EU sugar regime, the price of sugar imported into Europe from ACP sugar protocol countries was to be reduced by 36% between 2006 and 2009.

The final program consisted of 13 projects of which 8 were to be implemented by the Mauritius Sugar Industry Research Institute (MSIRI), 2 by the Sugar Research Institute of Fiji (SRIF), 1 by the Sugar Industry Research Institute of Jamaica (SIRI), 1 by the West Indies Central Sugar Cane Breeding Station (WICSCBS) and 1 by the Technical Services of the Swaziland Sugar Association (TSSSA).

The first contract for the implementation of the program was signed by the MSIRI in August 2010 and, subsequently, by the other research centres. The program is due for completion in December 2014.

Objectives

The principal objectives of the program are to

- Increase productivity, profitability and sustainability of the respective sugar industries of the ACP countries by surmounting common challenges through institutional collaboration in R&D and information exchange
- Enhance the capability of the sugar industries in ACP countries to make the transition to (and exploit the opportunities of) a more open and less protected sugar market
- Increase the competitiveness of the sugar industry in ACP countries

Implementation of the Program

The ACP Secretariat set up a Coordination Unit by an international restricted call for tender. The successful tenderer was SOFRECO a French company which is active in sugarcane research in Africa and elsewhere. SOFRECO appointed Mr Jean-Cyril Dagallier, who was seconded from CIRAD, to be the Coordinator for the project. He is located in Brussels in close proximity to the ACP Secretariat.

The Coordination Unit has the following functions

- Financial and administrative management of the program including auditing and monitoring
- Overall program coordination
- Monitoring of implementation of projects
- Reporting to ACP Secretariat as Regional Authorising Officer (RAO)

A Steering Committee was set up consisting of one representative of the RAO (Chair), the Chief Executive Officers of the Research Stations that were awarded projects, Chairperson of the Scientific Advisory Group, one representative of the EU, and the Coordinator (Observer/Secretary). The roles of the committee are to

- Provide guidance to the implementation process,
- Prepare annual work programs,
- Discuss and examine six-monthly progress reports,
- Contribute to coherence and complementarity of the actions within the Accompanying Measures for Sugar Protocol countries.
In addition, a Scientific Advisory Group was established by the Steering Committee. It consists of three renowned sugar researchers from within and outside the ACP region. This group provides comments to the 13 research projects funded in the program and also to the Coordination Unit and the Steering Committee. The principal role of the Group is to review scientific progress in years 1, 3 and 5 as follows:

- In year 1, they provide comments on proposed projects and provide suggestions on improvement, if any, of the scientific quality or approach of the projects.
- In years 3 and 5, they review the scientific reports on the 13 projects and provide comments.

Themes

There are three themes in the program:

- **Theme 1**: To stimulate the development of new sugarcane varieties that are better adapted to the future requirements of the sugar industry in ACP countries (5 projects of EUR 3,608,883).
- **Theme 2**: To reduce the costs of sugarcane production while, at the same time, reduce negative environmental externalities (4 projects of EUR 2,193,105).
- **Theme 3**: To reduce losses in sugarcane processing and increase the revenues from by-products such as ethanol and electricity (4 projects of EUR 3,203,628).

Theme 1

Theme 1 consists of four projects that should produce useful results for ACP countries and one high-risk project that has great potential benefit for all sugar-producing countries if it is successful. We believe this is a balanced portfolio of projects that will benefit all ACP countries. A brief description of the projects follows.

**Improving the capacity of sugarcane breeding in the Caribbean by investing in state-of-the-art laboratory equipment**

The sugarcane breeding station in Barbados invested in a Spectracane analysis system (Berding and Marston, 2010) in 2006. This system is based on NIR spectroscopy and is probably the best system available for measuring sugar and fibre content in samples of sugarcane from selection programs. It is efficient and reliable, and has proved to be very effective in Barbados. The aim of the project is to provide the same equipment to the selection programs in Jamaica, Guyana and Belize. The equipment is important as the West Indies has an innovative program to breed multi-purpose varieties that can be used for both sugar production and cogeneration. It is important to sample a large number of varieties for sugar and fibre content in the early stages of selection and the Spectracane system is ideal for the purpose.

**Increase sugarcane productivity through high sucrose and early ripening genotypes**

Following a reduction in the price of sugar paid by the European Union, the Mauritius sugar industry has been transformed to be a much more efficient industry. There has been centralisation of sugar mills and the milling period has been extended, mainly by starting the harvest earlier in the year.

At present, there is a lack of high performing varieties for early harvest, and the industry would also benefit from an increase in sugar content throughout the harvest season. Provision of early-ripening/high-sugar varieties would lead to an increase in productivity, profitability and sustainability.

The project involves evaluation of parent varieties for sugar content for early, mid and late harvest and breeding with parents with high early sugar content to improve sugar content early in the season. It will also be possible to breed for sugar content throughout the harvest season. Varieties with improved sugar content will be available to other ACP countries.
**International quarantine facility for the exchange of sugarcane germplasm among ACP countries**

Some 120 diseases have been recorded on sugarcane. The most important diseases are transmitted by cuttings and are referred to as systemic diseases. There have been 28 systemic diseases recorded and the most common mode of spread is through exchange of varieties between countries. The risks from these diseases may be severe.

Transmission of diseases can be avoided by quarantine of germplasm and effective testing for diseases while the plants are in quarantine. The most effective tests use molecular tools which have been developed over the last 20 years.

In this project, an international quarantine station is being set up in Mauritius, and it will facilitate the transport of disease-free germplasm to ACP countries. It will also enable ACP countries without a breeding program to access useful varieties for them to test under their conditions. Varieties developed in projects funded in the ACP program will be available for all ACP countries.

The quarantine house has been established and will start to accept varieties in 2013.

**A comparative study of family and mass selection methods as early selection criteria**

Traditionally, sugarcane breeding stations plant very large populations of seedlings in Stage 1 of their selection programs and use mass (individual) selection to choose varieties for the next stage of selection. Quantitative genetic studies have shown that this is reasonably efficient for the selection of sugar content but very inefficient for yield of cane as most of the variation observed is environmental, not genetic.

Research conducted in Australia (Stringer et al., 2010) has shown that selection of families for yield of cane and sugar content, followed by individual selection in the best performing families, leads to increased gain from selection compared with individual selection. In Australia, harvesting and weighing of plots is all mechanised, and this does not occur in many other programs. As a result, family selection for yield of cane is not practised routinely in any other selection program so that selection tends to be inefficient.

This project to be conducted in Fiji was designed to investigate whether it is feasible to use family selection when harvesting is manual, as proposed by Stringer et al. (2010). The project will also investigate the relative gains from selection for family selection and individual selection. If the project is successful and shows good gains from selection, the methodology could be used by other breeding programs.

**Nobilisation of Erianthus species**

The genus *Erianthus* has been of great interest to sugarcane breeders for many years due to its outstanding vigour and ratooning ability, resistance to pests and diseases, and tolerance to abiotic factors such as drought and flooding. It does, however, have low sugar content. Unfortunately, very few breeding stations have been successful in making fertile crosses with *Erianthus*. The major exception is China where there has been considerable success.

Several crosses with *Erianthus* have been made in Fiji, and the putative hybrids looked very interesting, so this project was initiated. To date, all of the putative hybrids tested by molecular methods have proved to be selfs of *Saccharum officinarum*, but further tests and crosses will be made. The potential for making impressive gains from selection if hybrids can be produced is considerable, but this is a high-risk project.

**Theme 2**

There are four projects in theme 2 covering control of pests, phosphorus fertilisation, and irrigation. All projects should lead to improved agricultural practices which will have a beneficial effect on the environment.
**Use of biopesticides for the control of sugarcane white grubs**

This is a joint project between the Mauritius Sugarcane Industry Research Institute and the South African Sugar Research Institute. The rationale for the project is that existing control measures using chemicals are not very effective as the pests develop resistance to the chemicals and because, frequently, identification of the grub species is incorrect and the control measures are very specific to particular grubs. It should be emphasised that white grubs are the larvae of scarabeid beetles and all species are similar morphologically, leading to misidentifications. White grubs are a major problem in the West Indian Ocean Islands of Mauritius, Reunion and Madagascar and in southern Africa.

Biopesticides are biological agents such as fungi, viruses, protozoa, nematodes or bacteria that are capable of killing grubs. In the project, dead grubs are being examined for such agents, and tests are being conducted to see if the responsible agents can be mass-produced and capable of killing a high percentage of the target species. Biopesticides are very species-specific, so it is also important that accurate methods are developed for identification of the grubs. Molecular methods for accurate identification are being developed.

**Regulating phosphorus in sugarcane to decrease production costs and to protect fresh water resources in ACP states**

Phosphorus (P) is a major source of pollution of water resources in all sugar-producing countries. P is the limiting nutrient influencing eutrophication, and relatively low levels of P are required to trigger eutrophication. This level is much lower than the level of P for optimum plant growth. Consequently, there is every chance that there could be high concentrations of P in runoff.

The project is aiming to better match P inputs to optimise sugarcane production. At the same time, it is also necessary to control P already in the soil to prevent movement to surface waters. The objectives of the project are to develop a soil test to indicate the environmental status of sugarcane soils, determine the field site’s vulnerability to erosion and runoff, and develop a P index to identify critical source areas in a watershed.

**Increasing sugarcane yields for small holder farmers through improvements in irrigation scheduling**

A study has shown that smallholder farmers in Swaziland do not follow any form of irrigation scheduling. This has led to potential losses in irrigation water, increase in electricity costs, leaching of nitrogen fertilisers, aggravated soil losses and, therefore, pollution of the environment, and an increase in weeds and weed control costs.

The study has shown clearly that smallholder farmers have significantly lower productivity than the sugar estates and larger farmers.

The project was designed to provide training for selected smallholder growers who would be used as extension service collaborators. The selected growers have received information on irrigation scheduling techniques and they have learnt about timely application of the correct amount of water. The growers receive regular advice via the use of mobile telephones.

**Efficient conjunctive use of water for sustainable sugarcane production**

Water is a limited resource in many countries, including Mauritius. As a result, there is increased competition for water for irrigation as domestic use of water is continually increasing. There is a need for higher productivity per unit of water applied.

The aim of the project is to develop an integrated approach to water management so that rainfall is used in conjunction with irrigation to increase water use efficiency and to reduce operational costs.

A decision-making tool for management of different irrigation systems on farms is required to optimise water management. The decision-making tool will be called IMIS (Irrigation Management Information system), and it will be user-friendly and provide site-specific information.
Theme 3

There are four projects in theme 3 that cover a broad range of objectives ranging from measurement of dextran to production of bio-plastics. Three of the projects deal directly or indirectly with co-products.

**The development of an alternative method for determining dextran in process material for ACP sugar producing countries**

Accumulation of dextran is a problem of post-harvest cane deterioration. Even if systems are in place to control post-harvest cane delays, uncontrollable factors such as rain, transport or social problems, mechanical breakdowns at factories and accidental cane fires do occur, resulting in cane deterioration, particularly if the cane is burnt. These problems are more severe in tropical regions and where the cane is produced by small growers. Detecting and quantifying cane deterioration as the cane enters the factory allows corrective actions to be taken such as the identification of the supplier who can therefore be helped, blending of the cane with fresher cane, increased sanitation at the mill and the use of chemicals.

Dextran is a good overall indicator of cane deterioration. A commercial firm and the Sugar Industry Research Institute in Jamaica investigated (Singleton *et al.*, 2002) an analytical approach which, if successful, would allow the determination of dextran in cane extracts rapidly and reliably by factory personnel. The project objectives involve the testing and development of this new analytical approach. Once validated and found acceptable, the method will be refined and the final procedure written. The procedure will then be distributed to selected ACP countries to collect sufficient data in order to obtain a wide range of dextran concentrations.

**Assist ACP sugar producer countries in making efficient use of energy resources in sugarcane processing by providing consulting and training**

This project involves a survey of energy management procedures, an analysis of training needs relevant to energy systems and their operations, the preparation and introduction of a software package for energy studies, and cooperation towards improving energy management in ACP countries.

Energy is becoming more and more important in cane sugar factories. This is linked to the possibility of generating electricity for the grid, either from bagasse only or from bagasse and another fuel during the off season. Another possibility is the use of bagasse for by-products such as paper, furfural, animal feed, or specific fermentations. Managing and optimising the energy usage in the cane factory either releases bagasse for other uses or allows the production of steam for other applications. Twelve ACP countries were visited, information was collected, and training needs towards energy management assessed.

If necessary, preliminary training was carried out. A software package was developed and tested; it was then used to model energy utilisation in factories. Training was provided in using the software in ACP countries.

**Technology development for disposal of vinasse by incineration**

When this project was reviewed in 2011, it was recommended that a thorough desk top study be carried out before undertaking any other activities. This has been completed and a number of technical unit operations identified, described and assessed in terms of relevance to vinasse treatment, costs and environmental impacts. Equipment, including incinerators, has been identified; information on costs and suppliers was obtained. The characterisation of the chemical composition of vinasse will be undertaken.

This project is difficult but, if successful, will be of great value. It is, however, less certain to be completely successful because of the complex nature of vinasse and the costs of the technologies involved in its treatment. The information generated from the project will, however, be extremely useful in assessing new technologies or breakthroughs in the future.
Production of poly (3-hydroxyalcanoates) bio-plastic from sugarcane biomass

After the 2011 review, it was decided that it should concentrate on the potential to produce bio-plastics from vinasse rather than from bagasse and sugar only. External inputs to identify suitable microorganisms and to develop techniques for the recovery of the bio-plastics will be sought.

Conventional plastic does not degrade well in the environment; it pollutes both the land and the oceans, affecting animals and fish. Technically, it is possible to convert carbohydrates into biodegradable plastic, but the costs are high and the technologies not well defined. A major cost contributor can be the raw material used; in this respect, vinasse and bagasse could be attractive. An extensive desk top study was completed; it provides a solid foundation to the project. The selection of raw materials for the production of bio-plastic has been reviewed, and pilot plants producing bio-plastic were visited. As was the case with vinasse, complete success here is less certain. The information generated will, however, be the foundation of assessment for new technologies or equipment for bio-plastic production.

Discussion

The program has a good range of projects, but it is unfortunate that so few countries are actively involved. This is probably a result of the long time after the initiation of the proposed program and its implementation, which caused many people to think that it would never happen. If the program continues after 2014 with a new round of funding, we would expect many other countries to submit proposals so that there would be a better spread of projects funded. In particular, more projects in Africa would be desirable as there is considerable potential for the expansion of the sugar industry in Africa.

It is traditional to concentrate on the technical advantages of research programs such as the ACP sugarcane research and development program. There are, however, a number of other benefits. Interaction and cooperation among cane sugar technologists is actively encouraged through visits, participation in common projects, training, publishing and attendance at technical events. Workshops are organised where all researchers discuss the work done, the goals achieved and the future prospects; at the last workshop in Mauritius, 14 countries were represented by 71 delegates including 30 foreign ones. This type of interaction is of considerable benefit to researchers who may not have the opportunity to meet peers and colleagues through other channels. The program also exposes researchers to current and important areas for research and development, providing equipment and support for the selected projects. It should be emphasised that, without the financial resources provided by the EU, none of the research centres concerned would have had the means to undertake the projects. The more so that, with the reduction in price of sugar, many countries were down scaling their research facilities, right sizing if not downsizing their scientific and technical staff, and narrowing their research avenues. The EU funding is, therefore, considered to be of considerable relief to the research centres in the 14 different countries directly involved and to contribute to the progress of the sugarcane industries of the ACP countries through advancement in knowledge on sugarcane and its industrial processes.

One important point is that one of the projects (in Swaziland) aims specifically at the management of water, a vital resource, by outgrowers. It is rare that this category of producers is aimed at in research programs. Furthermore, as many industries have a strong component of outgrowers providing canes to the mills, while some like in Kenya rely solely on outgrowers which supply 88% of the cane, research efforts for the benefit of this category of stakeholders should be enhanced in future.

Agricultural research and development provide high positive returns on investment (Alston et al., 2000; Evenson, 2001). It is vital that research project proposals are scrutinised before selection and implementation to ensure that they will benefit the communities concerned given that research remains risky. It is of paramount importance that successes make up for projects which fail.
to reach the objectives targeted and have no positive impact despite the resources and hopes contained in them.

With the significant reduction of 36% in the price of 1.3 M tonnes of sugar imported annually from the 18 ACP sugar protocol countries, their industries were to experience considerable setback, and national adaptation strategies had to be designed. It is interesting to note that some of these countries e.g. Belize, Fiji and Tanzania have included, in their strategies, additional investment in sugarcane research and development. It would be important that these initiatives complement those of the ACP Sugar Research Program.

If the current program meets its objectives and ambition, it would pave the way for a 2\textsuperscript{nd} program which should aim at:

**Enhanced production**
- New varieties and new canes
- Disease and pest control
- Novel methods of bulking new cane germplasm

**Sustainable production**
- Soil management
- Water management
- Adaptation to climate change
- Coping with environmental stresses

**Improved Processes**
- Milling of new canes
- Improving milling and refining processes
- Managing integrated production system

**Value Addition**
- Use of total cane biomass
- Second generation of products: cellulosic ethanol, gasification and torrefaction of bagasse
- High value organic substances
- Exploitation of other energy crops

All four avenues imply better management, capacity building, supply chain optimisation, quality control, etc. It is hoped that the new program will build on the achievements of the current one and will involve a much larger number of scientists and research centres of the ACP sugar producing countries which number 38 in total. Sugarcane as a crop has a bright future given that it will be a source of food both for human and animal consumption, it will provide clean renewable and sustainable energy in the form of ethanol and electricity, and it will contribute to a low carbon economy which is needed by the world. As it will address major societal challenges of the years ahead, no effort should be spared to exploit its full potential through research and development.

**Acknowledgements**

The ACP Sugar Research Program would have never materialised without the sustained efforts since 1999 by various personalities and parties to whom tribute should be paid. They include Mr Viwanou Gnassounou, Expert, All Commodity products, Department of Sustainable Economic Development and Trade, ACP Secretariat, their excellencies the Ambassadors of the ACP Sugar Protocol countries in Brussels through their Subcommittee on Sugar chaired by HE Patrick Gomes, Ambassador of the Republic of Guyana, the staff of the embassies in particular Mr Nidhendra Singh, Counsellor, Embassy of Fiji, Chair of the Technical ACP Subcommittee on Sugar, the various representatives of the European Commission Directorates concerned, the latest one being Iustinian Pop, Program Manager, Rural Development, Food Security & Nutrition, EuropeAid, European Commission, the Chair and members of the ACP Scientific Committee on Sugar as well
as the Chief Executive Officers, Principal Investigators and Scientists involved in the various research centres. To them and to Mr Jean-Cyril Dagallier, Director of the Coordination Unit of the ACP Sugar Research Program, the authors of this paper would like to express their sincere thanks and deep appreciation.

REFERENCES


l’environnement, et la valeur ajoutée par le biais des coproduits. La mise en œuvre a débutée en 2010 dans les centres de recherche à Maurice, à Fidji, à la Barbade, à la Jamaïque et au Swaziland. Le programme comprenait 14 pays ACP. Il dispose d’une unité de coordination située à Bruxelles, est géré par un comité directeur tandis que l’aspect scientifique est supervisé par un groupe consultatif scientifique composé de trois chercheurs ayant une longue expérience de la canne à sucre. Les projets sont en bonne voie, en dépit de diverses difficultés au stade initial. Un atelier de travail pour la revue des projets à mi-parcours a eu lieu en octobre 2012 et le programme sera achevé en 2014. Des progrès substantiels ont été accomplis dans certains projets ; d’ici la fin du programme, la plupart des projets auront été achevés et ceux à plus longue échéance seront poursuivis par les centres de recherche concernés. Ce programme est un exemple concret de collaboration en matière de recherche pour faire progresser les connaissances sur la canne à sucre et exploiter davantage le potentiel de la biomasse de la canne. Un deuxième programme est en cours de préparation.

EL PROGRAMA ACP DE INVESTIGACIÓN Y DESARROLLO EN CAÑA DE AZÚCAR: EJEMPLO TANGIBLE DE UN EXITOSO ENFOQUE MULTIDISCIPLINARIO PARA MEJORAR EL CONOCIMIENTO EN CAÑA DE AZÚCAR

Por

J.C. AUTREY¹, D.M. HOGARTH² y G.R. LIONNET²

¹Consultor, Mauricio
²Consultor, Australia

jcautrey@intnet.mu

PALABRAS CLAVE: Investigación, Desarrollo, Colaboración, Sostenibilidad, Competitividad.

Resumen

LOS INVESTIGADORES DE LOS ESTADOS Africanos, Caribeños y del Pacífico (ACP), miembros del Protocolo del Azúcar de la Convención Lomé que se tiene con la Unión Europea, determinaron que era de vital importancia realizar esfuerzos colaborativos en investigación y desarrollo en caña de azúcar. En 1999 se identificaron doce áreas prioritarias y se diseñaron proyectos de investigación para incrementar la productividad, rentabilidad, sostenibilidad y competititividad de las industrias azucareras del ACP. Se contó con fondos del orden de 13 M de Euros del 9º Fondo para el Desarrollo Europeo(EDF), los cuales estuvieron disponibles en 2007 a través de un convenio entre la UE y la Secretaría del ACP. Los trece proyectos seleccionados se agruparon en tres grandes temas: Desarrollo de nuevas variedades altamente productivas, Reducción del costo de producción al reducir factores externos negativos del ambiente y Adición de valor mediante el recurso de los co productos. La implementación se inició en 2010 en centros de investigación de Mauricio, Fiji, Barbados, Jamaica y Swazilandia. El programa incluyó 14 países miembros de la ACP. Tiene una Unidad Coordinadora localizada en Bruselas y es administrada por un Comité Directivo y su desarrollo es supervisado por un Grupo Científico Asesor conformado por tres investigadores expertos en caña de azúcar. Los proyectos van bien encaminados a pesar de varias dificultades que
se presentaron en sus etapas iniciales. Un Taller de Revisión Mid-Term fue organizado en 2012 y el programa concluirá en 2014. Se ha obtenido un progreso substancial en algunos de los proyectos y al final del programa, la mayoría estarán finalizados y aquellos que necesiten más tiempo, serán concluidos por los centros de investigación a cargo. Este programa es un ejemplo tangible de investigación colaborativa para mejorar el conocimiento que se tiene en caña de azúcar y explotar sustancialmente y de mejor manera la biomasa de la caña. Un segundo programa está en planificación.

**O PROGRAMA DE PESQUISA E DESENVOLVIMENTO DE CANA-DE-ACÚCAR ACP: UM EXEMPLO TANGÍVEL DE UMA ABORDAGEM MULTIDISCIPLINAR DE SUCESSO PARA AVANÇAR O CONHECIMENTO EM CANA**

Por

J.C. AUTREY¹, D.M. HOGARTH² e G.R. LIONNET²

¹Consultor, Maurício
²Consultor, Austrália

jcautrey@intnet.mu

PALAVRAS-CHAVE: Pesquisa, Desenvolvimento, Colaboração, Sustentabilidade, Competitividade.

**Resumo**

ESFORÇOS COLABORATIVOS EM PESQUISA e desenvolvimento em cana-de-açúcar são considerados de importância vital por pesquisadores de países da África, do Caribe e do Pacífico (ACP), membros do Protocolo de Açúcar da Convenção de Lomé entre a União Europeia e os Países ACP. Foram identificadas doze áreas de prioridade em 1999 e desenvolvidos projetos de pesquisa para aumentar a produtividade, a rentabilidade e a sustentabilidade, assim como a competitividade das respectivas indústrias de açúcar dos países ACP. Um fundo de cerca de 13 milhões de euros do 9º Fundo de Desenvolvimento Europeu (EDF) foi disponibilizado em 2007 por meio de um acordo entre a UE e a Secretaria dos países ACP. Os 13 projetos selecionados foram agrupados nos três temas principais a saber: Desenvolvimento de novas variedades de cana-de-açúcar altamente produtivas, Redução do custo de produção simultaneamente à redução de externalidades ambientais e Adição de valor por meio de recurso a coprodutos. A implementação teve início em 2010 em centros de pesquisa em Maurício, Fiji, Barbados, Jamaica e Suazilândia. O programa envolveu 14 países ACP e possui uma unidade de coordenação em Bruxelas. Ele é administrado por um Comitê Diretor e sua ciência é supervisionada por um Grupo Consultor Científico composto por três pesquisadores eminentes de cana-de-açúcar. Os projetos estão em andamento, apesar de várias dificuldades no estágio inicial. Um Workshop de Avaliação Intercalar foi realizado em outubro de 2012 e o programa será concluído em 2014. Progresso substancial foi alcançado em alguns projetos e, ao final do programa, a maioria deles terá sido concluído e, aqueles com prazos mais longos terão prosseguimento pelos respectivos centros de pesquisa envolvidos. Este programa é um exemplo tangível de pesquisa colaborativa para avançar o conhecimento em cana-de-açúcar e explorar, mais substancialmente do que no presente, a biomassa da cana. Um segundo programa está sendo elaborado.
OPTIMISATION OF HARVEST RESOURCES IN A COLOMBIAN SUGAR MILL BY USE OF SIMULATION MODELS

By
L.G. AMU¹, J.A. GARCIA², D.E. GALVIS¹ and O. RUBIANO²

¹Manuelita Sugar Mill, Palmira, Colombia
²School of Industrial Engineering and Statistics, Universidad del Valle, Cali, Colombia
luis.amu@manuelita.com

KEYWORDS: Harvest Logistics, Simulation Modelling, Optimisation, Sugarcane Transportation.

Abstract
This paper presents a mathematical model simulating the sugarcane supply system in a Colombian sugar mill that assigns resources (trucks, loader machines and workers) to the harvest group in an optimal way, according to the daily crushing requirement, the transportation costs and sugar mill procedures. The model was developed in Excel and the simulation and optimisation were run with specialised software of stochastic simulation. The statistical distribution and parameters for each process activity were identified by analysing the information recorded in Manuelita sugar mill between 2007 and 2010. Sensitivity analyses were performed and the limitations and bottlenecks of the system were identified. The optimisation model established the resources that should be allocated to each harvest group to reach the daily supply of cane required by the mill. A transportation cost matrix was developed to define the type of transport to use based on the distance from the field to mill, and Analytic Hierarchy Process (AHP) methodology was used to select the order of the sugarcane farms for harvest. For the case studied, it was found to be necessary to have available at least 30 vehicles, 776 cane cutters, 14 combine harvesters and 6 loader machines to meet at least 85% of the daily crushing requirements above 9000 tonnes. Some results of the model were implemented in the sugarcane supply system studied to eliminate unproductive activities allowing for 5% better utilisation of the resources, generating savings in operating costs greater than US$200 000 per year.

Introduction
The logistics management of supply systems for the production of sugar and alcohol is a challenge when it comes to improving and maintaining efficiencies beginning with coordination between agricultural activities (field) and industrial processes (factory) (Hahn and Ribeiro, 1999). The amount of resources that are managed and variability in the activities involved in sugar processing require the application of specialised tools that help, from a holistic point view, to make the right decisions before, during and after the operations. The goal of cane supply is to supply cane to the mill in the amounts agreed, when required and making best use of resources. However, the lack of effective tools that can predict the behaviour and impact of a decision can result in expensive actions that do not always yield the expected results.

Harvesting costs, including transportation, in the countries where sugarcane is cultivated, represent a large proportion of total production costs, 25 to 35% of the total. In Colombia, the transport of sugarcane has been studied in order to improve efficiencies by redesigning equipment, strengthening systems and logistic control programming, and has involved the expansion of private
road infrastructure and field layouts, as it constitutes about 34% of total variable cane harvest costs (Ramirez and Garcia, 2006).

An aspect that influences efficiency in the supply chain is vehicle lost time when they are waiting to load in the field and to unload in the mill. It is estimated for the Colombian sugar industry that about 60% of the average time that the vehicles remain in the unloading area is downtime.

Similarly lost time accounts for about 50% of the average time that these vehicles are in the loading area (Amu et al., 2007).

The application of mathematical tools to suggest improvements in the cane supply system has already been used by different authors in the world.

Hansen et al. (1998) focused their simulation models on reducing cut to crush delays, providing a holistic view regarding the various processes involved in the sugarcane harvesting and delivery system, in a case study of South Africa.

Le Gal et al. (2004) showed that it is possible to increase production by up to 5% and transport capacity by 35% through simulation with a better supply of sugarcane in the region of Sezela in South Africa.

Ianonni and Morabito (2006) showed a 13.5% reduction in waiting times of vehicles when they simulated strategic changes in the dispatch rules of the vehicles in the Brazilian sugar industry.

Higgins et al. (2004) demonstrated potential reductions between AU$1.00 and AU$2.50 per tonne of sugarcane and 95% decrease in the delays in Australia by simulation models of harvesting and transportation of sugarcane.

The purpose of this paper is to present the formulation of a simulation model designed to analyse the structure of the cane supply chain to optimally allocate resources to harvest. The mathematical model was developed in Excel and run with Crystal Ball ® stochastic simulation software.

To support the model, a matrix of transportation costs was developed that determines the type of vehicle to be used based on the distance from the harvest group to the mill. Analytic Hierarchy Process (AHP) methodology was applied to select the sequence of the sugarcane farms to be harvested (Garcia and Fernandez, 2010).

Some suggestions for the optimal allocation of the resources provided by the model were validated by the Promodel ® software before implementation in the sugar mill.

Materials and methods

The data were collected from October 2007 until December 2010 by the database system for agricultural management of the sugar mill and from information in real time during operations.

Development of the simulation and optimisation model

Having identified the parameters for each of the critical variables in the sugarcane supply chain, a simulation model, SIMCOS, was developed to understand the relationship between processes, the presence of bottlenecks and their causes, as well as optimising the allocation of resources to the operations.

The way that SIMCOS operates, combining simulation and optimisation, is shown in Figure 1. The simulation model takes as input data the statistical distribution of the variables defined and the simulation results are used to run the optimisation model, based on the constraints and the objective function raised.

Each solution of the optimisation model is shown graphically and the values of the variables of the optimal solution are preserved until the best feasible solution is found.

The simulation and optimisation stop when the maximum number of iterations or the simulation time determined by the user are reached, and the best solution is identified.
The simulation model

The simulation model was developed in Excel for the nine harvest groups each with their operating characteristics. The model is formulated to different scenarios with changes in the makeup and characteristics of the harvest groups. Table 1 shows the input variables, output variables and the decision variables of the simulation model.

The two binary decision variables, one for the convenience of using or not using additional wagons in the loading area at the field and the other for the convenience of using or not using additional wagons in the unloading area at the reception area at the mill, allow the model to define if additional wagons are required by some of the harvest groups to reduce the waiting time.

Table 1—variables of the model.

<table>
<thead>
<tr>
<th>Input variables:</th>
<th>Output variables:</th>
</tr>
</thead>
<tbody>
<tr>
<td>– Expected daily harvest for each harvest group</td>
<td>– Vehicles to be used by each harvest group (minimum, maximum, average, percentiles).</td>
</tr>
<tr>
<td>– Type of harvest for each harvest group</td>
<td>– Loader machines to be used by each harvest group (minimum, maximum, average, percentiles).</td>
</tr>
<tr>
<td>– Type of vehicle for each harvest group</td>
<td>– Combine harvesters to be used by each harvest group (minimum, maximum, average, percentiles).</td>
</tr>
<tr>
<td>– Type and capacity of wagon</td>
<td>– Wagons to be used by each harvest group (minimum, maximum, average, percentiles).</td>
</tr>
<tr>
<td>– Distance from each harvest group to the mill</td>
<td>– Cane cutters to be used per day by each harvest group</td>
</tr>
<tr>
<td>– Vehicle empty speed and full speed</td>
<td>– The delivery times of each harvest group</td>
</tr>
<tr>
<td>– Unload times for each wagon</td>
<td>– Average tonnes per vehicle per day</td>
</tr>
<tr>
<td>– Number of cane rail wagons</td>
<td>– Number of trips per day per each harvest group</td>
</tr>
<tr>
<td>– Efficiency of combine harvester and loader machines</td>
<td>Decision variables:</td>
</tr>
<tr>
<td>– Hours worked per day by each harvest group</td>
<td>Additional wagons in the loading area (binary variable)</td>
</tr>
<tr>
<td>– Efficiency of the cane cutters</td>
<td>Additional wagons in the unloading area (binary variable)</td>
</tr>
</tbody>
</table>

The optimisation model

The optimisation model is designed for the user to select the output variable that will be optimised. The optimisation model is focused on finding the values that minimise the amount of resources to meet the requirements of the mill crushing for a given period. For this case, it was defined that 85% of the time was required for crushing more than 9000 tonnes per day, and the other 15% was programmed for maintenance of the mill.
The model was run for different scenarios, and for the case study the objective for the model was defined as:

‘Minimise the total vehicles necessary’ under the following conditions:
- The average number of loaders machine required per day must be fewer than 8.
- The average number of combine harvesters required per day must be fewer than 14.
- The average number of cane cutters required per day must be fewer than 800.

**Decision variables**

The decision variable defined for the optimisation was the amount of cane to provide for each harvest group with the possible ranges shown in Figure 2. The model used 18 binary variables, two for each harvest group, with the second one for each group taking the decision to have (0) or not to have (1) additional wagon in the field area or in the reception area.

![Review decision variables and change properties as necessary](image)

**Constraints**

The constraints of the model are entered into the software through the window shown in Figure 3. The restrictions defined were:
- The daily supply of sugarcane by all harvest groups must be up to 9000 tonnes.
- Harvest groups 1, 7 and 8, must use fewer than 4 combine harvesters each day.
- Harvest group 9 must use fewer than 3 combine harvesters each day.
- The daily average amount of whole stalk sugarcane must not exceed 5500 tonnes.
- The daily supply of whole stalk sugarcane must not exceed the capacity of the loader machines.

The model was run to find the optimal conditions, simulating 1000 iterations per each feasible solution. It stops after 1000 feasible solutions.

**Selecting the harvesting sequence**

The AHP method was used to establish the criterion that prioritises the harvest of sugarcane farms. This method determines mathematically the degree of importance or weight of different established criteria according to the cut to crush delay and the procedures of the mill. Alternatives were evaluated to find the sequence of the farm to be harvested, from higher to lower priority. Table 2 presents the criteria evaluated.
Fig. 3—Constraints of the model.

Table 2—Evaluation criteria to the AHP.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead time</td>
<td>Time between the cutting or burning of the cane in the</td>
</tr>
<tr>
<td></td>
<td>field and the crushing in the factory.</td>
</tr>
<tr>
<td>Type of tenure</td>
<td>Ownership of land</td>
</tr>
<tr>
<td>Amount of cane available</td>
<td>Tons of cane in the farm.</td>
</tr>
<tr>
<td>Distance</td>
<td>Distance from the farm to the mill</td>
</tr>
</tbody>
</table>

Model validation

The model was validated using scenarios with various operating conditions with data from June 2011 obtained from the databases of the agricultural management system. The data of June 2011 were compared to the results of SIMCOS.

A daily average of tonnes of sugarcane provided by each harvest group and the real distance from them to the mill were the input data to perform the simulation. Table 3 shows both simulation and real data. Note that the model largely reflects reality, especially in the requirement of daily vehicles, which is a main variable in this model.

Table 3—Actual results versus results of SIMCOS.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Actual data June 2011</th>
<th>Simulation results</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Average</td>
</tr>
<tr>
<td>Tonnes of sugarcane per day</td>
<td>8525</td>
<td>8525</td>
</tr>
<tr>
<td>Daily average distance</td>
<td>19.2</td>
<td>19.2</td>
</tr>
<tr>
<td>Tonnes by vehicle per day</td>
<td>271</td>
<td>292</td>
</tr>
<tr>
<td>Total vehicles per day</td>
<td>31.4</td>
<td>31.7</td>
</tr>
<tr>
<td>Combine harvesters per day</td>
<td>12</td>
<td>13</td>
</tr>
<tr>
<td>Cane cutters per day</td>
<td>737</td>
<td>727</td>
</tr>
<tr>
<td>Loader machines per day</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Wagons per day</td>
<td>173</td>
<td>164</td>
</tr>
</tbody>
</table>
Another validation of the model was performed with the Promodel ® software (this software is a discrete-event simulation technology that helps to make better decisions faster. It is used to plan, design and improve new or existing manufacturing, logistics and other tactical and operational systems).

In this case, one of the feasible solutions was remove one of the whole stalk sugarcane harvest groups. This solution was simulated in Promodel comparing the amount of sugarcane supplied to the mill and the efficiency of the vehicles (Garcia and Fernandez, 2010).

The simulation results showed that removing one of the whole stalk sugarcane harvest group does not affect the daily amount of sugarcane supplied to the mill, therefore the efficiency of some vehicles is improved.

**Results and discussion**

Nine harvesting groups were considered in the model and, for each of them, the amount of sugarcane provided to the mill, the type of harvesting, the type of transport vehicle, the type of wagon and the number of wagons per each trip, etc., was defined as shown in Figure 4. This information represents the initial data for the simulation.

The optimisation model was run looking for the minimum number of vehicles needed to reach daily crushing requirements greater than 9000 tonnes at least 85% of the time, the minimum and average quantity of combine harvesters, loader machines, cane cutters, etc., and the daily average tonnes of sugarcane to be assigned to each harvest group.

Figure 5 shows the results of the optimisation based on 1000 iterations to get the optimal solution. The simulated case began with a solution of 37 vehicles and the optimal solution suggests 33 vehicles on the 85 percentile.

Figure 6 shows it is necessary to have a minimum availability of 6 loader machines, 14 combine harvesters and 770 cane cutters to achieve the planned objective.

The tonnes assigned to each harvest group by the model are shown in Table 4, where it estimates that the amount of cane supplied by harvest groups 2, 3 and 4 could be supplied only by two of them.

This suggestion was validated with simulations in Promodel and applied in the sugar mill, getting the expected results.
Fig. 5—Feasible results of SIMCOS.

![Figure 5](image)

Fig. 6—Best solution of SIMCOS.

![Figure 6](image)

Table 4—Assignment of tons to the harvest groups by SIMCOS.

<table>
<thead>
<tr>
<th>Decision variables</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harvest group 1 (tons per day)</td>
<td>1483</td>
</tr>
<tr>
<td>Harvest group 2 (tons per day)</td>
<td>463</td>
</tr>
<tr>
<td>Harvest group 3 (tons per day)</td>
<td>474</td>
</tr>
<tr>
<td>Harvest group 4 (tons per day)</td>
<td>2500</td>
</tr>
<tr>
<td>Harvest group 5 (tons per day)</td>
<td>645</td>
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<tr>
<td>Harvest group 6 (tons per day)</td>
<td>600</td>
</tr>
<tr>
<td>Harvest group 7 (tons per day)</td>
<td>1302</td>
</tr>
<tr>
<td>Harvest group 8 (tons per day)</td>
<td>1039</td>
</tr>
<tr>
<td>Harvest group 9 (tons per day)</td>
<td>500</td>
</tr>
</tbody>
</table>

**Sensitivity analysis**

Sensitivity analysis identified the variables that have significant impacts on the objective variable. The biggest impact on the number of vehicles required is the weight of cane carried on the wagons of harvest group 4 as shown in Figure 7. These wagons carry whole stalks. The negative bar in the figure indicates that greater weight of cane carried on wagons reduces the requirement for vehicles per day.

The model also identified that the load time of the wagons of the harvest group 4 influences the daily requirement of transportation vehicles significantly.
Conclusions

This paper presents an application of the principles of simulation and optimisation as tools for solving problems in a sugar mill, and it proposes a model with the objective to optimise supply parameters in the main process within the sugarcane value chain, whose quality properties are perishable and sensitive to the storage and transport time, before its processing.

The resources such as vehicles and wagons which supply cane to reach the daily requirement of milling, reducing milling downtimes due to lack of raw materials and high manufacturing costs by idle time. The case studied suggests that is necessary to have in operation a minimum availability of 33 transport vehicles, 770 cane cutters, 14 combine harvesters and 6 loader machines to achieve a daily crushing rate greater than 9000 tonnes at least 85% of the time.

Some of the strategies in the model were implemented and achieved the expected results. For example, where five harvest groups supplied whole stalk cane previously, four groups are now sufficient, which has allowed a reduction in transport vehicles and loader machines per day of approximately 5%, obtaining savings in operating cost greater than US$200 000 per year.

REFERENCES


OPTIMISATION DES RESSOURCES DE RECOLTE DANS UNE USINE DE SUCRE EN COLOMBIE PAR L'UTILISATION DE MODELES DE SIMULATION

Par

L.G. AMU¹, J.A. GARCIA², D.E. GALVIS¹ et O. RUBIANO²

¹Usine Sucrière de Manuelita, Palmira, Colombie
²Ecole de génie industriel et de statistiques, Université de Valle, Calt, Colombie

luis.amu@manuelita.com

MOTS-CLÉS: Logistique de Récolte,
Modélisation de Simulation,
Optimisation,
Transport de Canne à Sucre.

Résumé

CET ARTICLE PRÉSENTE un modèle mathématique simulant le système d'approvisionnement en canne à sucre dans une usine colombienne qui attribue de manière optimale les ressources (camions, machines chargeuses et les travailleurs) aux groupes de récolteurs, en fonction de l'exigence quotidienne de broyage, des coûts de transport et des procédures de la sucrerie. Le modèle a été développé en utilisant le logiciel Excel alors que la simulation et l'optimisation ont été réalisées avec des logiciels spécialisés de simulation stochastique. La distribution statistique et les paramètres pour chaque activité du processus ont été identifiés en analysant l'information enregistrée à la sucrerie de Manuelita entre 2007 et 2010. Les analyses de sensibilité ont été effectuées et les limitations et les blocages du système ont été identifiés. Le modèle d'optimisation définit les ressources qui devraient être allouées à chaque groupe de récolteurs afin d'atteindre l'apport quotidien de canne requis par l'usine. Une matrice des coûts de transport a été développée pour définir le type de transport à utiliser en fonction de la distance du champ à l’usine, et la méthodologie « Procédé Analytique Hiérarchique » [Analytic Hierarchy Process (AHP)] a été utilisée pour déterminer l'ordre dans lequel les fermes de canne à sucre seront récoltées. Pour le cas étudié, il a été jugé nécessaire de disposer d'au moins 30 véhicules, 776 coupeurs de canne, 14 moissonneuses et six machines chargeuses pour répondre à au moins 85% des besoins quotidiens de broyage de plus de 9000 tonnes. Quelques résultats du modèle ont été mis en application dans le système d'approvisionnement en canne à sucre étudié pour éliminer les activités non productives permettant ainsi une utilisation plus efficiente des ressources de 5%, et générant des économies dans les coûts de production de plus de US $ 200 000 par an.
OPTIMIZACIÓN DE LOS RECURSOS DE COSECHA EN UN INGENIO AZUCARERO COLOMBIANO USANDO MODELOS DE SIMULACIÓN

Por

L.G. AMU¹, J.A. GARCIA², D.E. GALVIS¹ y O. RUBIANO²

¹Ingenio Manuelita, Palmira, Colombia
²Escuela de Ingeniería Industrial y Estadística, Universidad del Valle, Cali, Colombia

luis.amu@manuelita.com

PALABRAS CLAVE: Logística de Cosecha, Modelos de Simulación, Optimización, Transporte de Caña.

Resumen
Este trabajo presenta un modelo matemático que simula el sistema de suministro de caña en un ingenio azucarero colombiano. Este asigna recursos (camiones, alzadoras y trabajadores) al grupo de cosecha de forma optimizada y según el requerimiento diario de molienda, los costos de transporte y los procedimientos del ingenio. El modelo se desarrolló en Excel y la simulación y optimización se corrieron usando un software especializado de simulación estocástica. Se identificaron la distribución estadística y los parámetros para cada actividad del proceso a través del análisis de la información registrada en el Ingenio Manuelita entre 2007 y 2010. Se realizó análisis de sensibilidad y se determinaron las limitaciones y los cuellos de botella del sistema. El modelo de optimización estableció los recursos que debían destinarse a cada grupo de cosecha para cumplir con la demanda diaria del ingenio. Para definir el tipo de transporte que se iba a usar, se desarrolló una matriz de costos que tomaba en cuenta la distancia del campo a la fábrica y se usó una metodología de Proceso Analítico de Jerarquía (PAJ) para seleccionar las fincas a cosechar. Para el caso de estudio, para cumplir con al menos el 85% del requerimiento diario de molienda que estaba sobre las 9000 toneladas, se determinó que era necesario contar con al menos 30 vehículos, 776 cortadores de caña, 14 cosechadoras combinadas y 6 alzadoras. Se implementaron algunos resultados del modelo en el sistema de alimentación estudiado para eliminar actividades improductivas permitiendo la mejor utilización de recursos en un 5% y generando ahorros en costos de operación mayores a los USD 200,000.00 anuales.
OTIMIZAÇÃO DE RECURSOS DE COLHEITA EM UMA USINA DE AÇÚCAR NA COLÔMBIA COM O USO DE MODELOS DE SIMULAÇÃO

Por

L.G. AMU¹, J.A. GARCIA², D.E. GALVIS¹ e O. RUBIANO²

¹Manuelita Sugar Mill, Palmira, Colômbia
²Escola de Engenharia Industrial e Estatística, Universidad del Valle, Cali, Colômbia
luis.amu@manuelita.com

PALAVRAS-CHAVE: Logística de Colheita, Modelagem de Simulação, Otimização, Transporte de Cana.

Resumo

ESTE TRABALHO APRESENTA um modelo matemático simulando o sistema de fornecimento de cana-de-açúcar em uma usina na Colômbia que atribui recursos (caminhões, carregadeiras e trabalhadores) à equipe de colheita de maneira ótima, de acordo com a exigência de moagem diária, os custos de transporte e os procedimentos da usina. O modelo foi desenvolvido em Excel e a simulação e a otimização foram realizadas com um software especializado de simulação estocástica. A distribuição estatística e os parâmetros para cada processo foram identificados pela análise das informações registradas na usina de açúcar Manuelita entre 2007 e 2010. Foram realizadas análises de sensibilidade e as limitações e gargalos do sistema foram identificados. O modelo de otimização estabeleceu os recursos que seria alocados a cada equipe de colheita para alcançar o fornecimento diário de cana exigido pela indústria. Uma matriz de custo de transporte foi desenvolvida para definir o tipo de transporte a ser utilizado com base na distância do campo à indústria e a metodologia do Processo Hierárquico Analítico (AHP) foi utilizada para selecionar a ordem das propriedades produtoras de cana para colheita. Para o caso estudado, foi necessário disponibilizar 30 veículos, 776 cortadores de cana, 14 colheitadeiras combine e 6 carregadoras para atender pelo menos 85% das exigências diárias de moagem de mais de 9000 toneladas. Alguns resultados do modelo foram implementados no sistema de fornecimento de cana estudado para eliminar atividades improdutivas, permitindo um uso 5% melhor dos recursos, gerando economia em custos operacionais superior a US$ 200.000 por ano.
IMPROVING SMALLHOLDER PRODUCTIVITY IN INDIA THROUGH CAPACITY BUILDING OF FIELD EXTENSION OFFICERS

By
HARSH VIVEK and RAJ PAL SINGH

International Finance Corporation (IFC), New Delhi, India
Correspondence address: International Finance Corporation (the World Bank Group), 3rd Floor, Maruti Suzuki Building, Nelson Mandela Marg, Vasant Kunj, New Delhi – 110070, India
harshviv@gmail.com; hvivek@ifc.org

KEYWORDS: Smallholder Productivity, Capacity Building, Field Extension Services.

Abstract
The ‘Mitha Sona Pariyojana’ (or the Sweet Gold Program), a sugarcane farm productivity enhancement project, implemented jointly by IFC and DSCL (Sugar) in Uttar Pradesh in North India, is an attempt to use the power of the private sector to address the productivity challenge in the sugar value-chain with the overall aim of improving farm incomes. Sugarcane farmers, especially in states like Uttar Pradesh and Bihar, continue to face challenges to enhance farm incomes on account of low farm yields due to the predominance of small and marginal landholdings and subsistence agriculture, and a poor agronomy package of practices. The program builds the capacity of DSCL’s field extension officers to strengthen farm extension and farmer training for productivity improvements. The independent evaluation of the project’s performance for a random sample of matched pairs of Project/treatment farmers and control farmers shows an average increase of 23% in the yield of treatment farmers in the first year and 87% in the second year from baseline productivity levels. Interestingly, in the first year, the yield of control farmers declined by 11% due to an attack of top borer whereas, in the second year, an average yield increase of 19% was registered even of control farmers on account of adoption of the agronomy package by some of the control farmers after seeing the results of project farmers. A majority of the farmers covered in the project are smallholders with average land holding of around 2 hectares.

Introduction
Stagnant farm productivity
Per the estimates of Indian sugar research institutions and associations, the sugarcane farm productivity has remained more or less stagnant in India, especially in the north Indian states. India’s average sugarcane productivity is ranging between 65 tonnes per hectare to 70 tonnes per ha for the past two decades.

However, there are wide regional variations in sugarcane productivity. For instance, states like Tamil Nadu have an average sugarcane yield above 100 tonnes per hectare, while states like Uttar Pradesh have per hectare productivity in the range of 55 to 58 tonnes. Even within Uttar Pradesh, there are regional variations with Western Uttar Pradesh recording a much higher productivity at 60 tonnes as compared to 45 tonnes per hectare in the Central or Eastern parts of the state.

Why is it that states like Uttar Pradesh, despite having a long track record of sugarcane cultivation, lag behind in yield as compared to the rest of the country? When compared to the South, one of the reasons for low yield is the relatively shorter grand growth season for cane in Uttar Pradesh (due to severe winters and summers for three months each which halts sugarcane production).
growth). However, climatic factors notwithstanding, there are a number of socio-economic factors that impede sugarcane yield in Uttar Pradesh such as lack of farmer awareness for good agronomy practices, lack of capacity to implement modern practices, constraints in access to farm inputs, including credit and improper information on good farm management practices such as quality of seed/variety, planting techniques, balanced nutrition according to soil health, critical stages of irrigation, plant protection and ratoon management (Indian Institute of Sugarcane Research, IISR, Lucknow, India).

**Business case: sugarcane farm productivity enhancement**

Sugar mills, across the country, and particularly in Uttar Pradesh have been facing shortages in cane drawl in the last few years. While installed capacity has increased over the last few years from 21.39 million tonnes in 2006–07 to 23.62 million tonnes in 2009–10, there has been a declining trend in the sugarcane acreage in the supply-area of the mills from 5.1 million hectares in 2006–07 to 4.1 million hectares in 2009–10, says the National Federation of Cooperative Sugar Mills, New Delhi, India. The reduction in acreage has been partly a result of declining interest of sugar companies towards sugarcane development as well as farmers in the command area shifting away from sugarcane cultivation to other competing (and perhaps more remunerative) crops like wheat and paddy.

The decline in sugarcane drawl has serious business implications for sugar mills. With insufficient sugarcane to crush, most sugar mills in Uttar Pradesh report sub-optimal capacity utilisation, which may result in operational losses, decline in production efficiency and increase in costs. In this context, making sufficient cane available to the mill in the crushing season becomes the top priority for the sugar mill. More sugarcane to crush implies more sugar to produce, leading to a better top and bottom line for the firms, and thriving business for the industry as a whole. Therefore, it is imperative for any sugar mill to encourage farmers, especially in its gate area to grow sugarcane.

In a simplistic economic scenario, a farmer’s decision to grow sugarcane is a function of the income from sugarcane vis-à-vis the income from other competing crops, as depicted in a simplistic equation below, other factors remaining constant (such as risks, capacity, climate, government policies etc.).

**Equation 1: farmer’s decision framework for sugarcane cultivation**

Farm income \((Y)\) is a function of price, quantity and cost of production, as depicted in the simplistic equation below, other factors remaining constant.

\[ Y = f(p \cdot q) - c, \text{where} \]

Assuming sugarcane price \((p)\) to be constant (as determined by the political establishment and, therefore, outside the domain of both the firms and the farmers), the income from sugarcane \((Y_s)\) increases if the percentage increase in quantity \((q)\) is higher than the percentage increase in costs.

In other words, if we can increase the farm yield without significant increase in the cost of production for sugarcane farmers, we can increase farm incomes from sugarcane cultivation. When farm income from sugarcane cultivation increases (difference between \(Y_s\) and \(Y_c\)), the opportunity
cost of sugarcane cultivation decreases. If income from sugarcane is higher than the income from other competing crops, the farmer will decide to plant sugarcane based on pure economics. With more sugarcane planted, there is likelihood for sugar mills to have higher drawl. Thus, there is a strong business case for sugar mills to help farmers increase farm productivity, without a commensurate increase in their cost of cultivation.

Materials and methods

The Mitha Sona Pariyojana to enhance farm productivity

With the above, well-established business-case in mind, IFC in collaboration with DSCL, launched the Mitha Sona Pariyojana (or the Sweet Gold Program) to demonstrate, on a pilot basis, a scientific and pragmatic approach to assist farmers increase farm productivity and incomes.

- Mitha Sona Pariyojana is a pilot project launched with 2000 select farmers across two mills of DSCL in Central Uttar Pradesh and later scaled-up to over 12 000 farmers across all four mills of the company. Launched in August 2009, the primary objective of the project is to enhance farm productivity of these 2000 farmers by over 25% from the baseline productivity levels over a three-year period. The project works through building capacities of the company’s extension workers, who in turn build farmer capacities on sugarcane practices under supervision from the project team and experts. The main components of project design are as follows:

  - Diagnostic study of the area:

Before formulating a sugarcane development project in the command area of the sugar mills, an in-depth diagnostic study of the area was conducted. All factors like climatic conditions, soil types, irrigation resources, size of farm holdings, constraints and strength for sugarcane cultivation, diversion of sugarcane, absentee landlords etc were thoroughly examined.

During the detailed diagnostic study, some of the relevant issues emerged such as cultivation of old, obsolete varieties by farmers; poor soil health with very low (less than 0.30%) organic carbon in more than 50% samples while 2.5 to 3.0% organic carbon is necessary for sustainable crop production (Bhandari, 1998).

It has been observed that there is lack of irrigation resources on one hand and practice of flood irrigation on the other. The knowledge of farmers about scientific and suitable agronomy packages particularly regarding planting techniques and balanced application of various inputs such as fertilisers and pesticides is inadequate. It is well established that lack of proper advice and guidance on good planting techniques is one of the major constraints in enhancing productivity of sugarcane (Lal Banwari, 1989).

Similarly, studies have revealed that lack of communication, inadequacy of water, and delayed supply of inputs are major constraints in adoption of balanced nutrition in agriculture (Athimuthu, 1990).

Researchers have also attributed lack of information as one of the major constraints in the utilisation of proper plant protection methods (Jeeva and Ramchandran, 1999). Most of the farmers apply only nitrogen and that too inadequately for plant cane. There is hardly any fertiliser application in ratoon crops resulting in poor ratoon cane yields. Adequate and balanced application of fertilisers based on soil test is necessary to sustain soil and crop productivity (Singh and Yadav, 1992).

- Development of a scientific agronomy package of practices:

The project team undertook development of a systematic and scientific package of practices for sugarcane farmers suitable to the agro-climatic and socio-economic conditions of the area on the basis of findings which emerged from the ‘diagnostic study’ to assess the existing practices by farmers, and developed the recommended package in consultation with the company.

- Development of a comprehensive training manual for company’s extension workers:

Training and capacity building of the company’s extension workers is at the core of the project as it is the extension workers who have the maximum interface with the farmers, and in turn the maximum influence on their behaviour and practices. A comprehensive and illustrated training manual (practical handbook) has been prepared in local vernacular for the extension workers covering all major aspects of sugarcane agronomy like varietal identification and selection,
Management

integrated nutrition management, integrated pest management, ratoon management, recommended irrigation and harvest practices. The following major training tools have been used:

- Handbook on all improved packages of practices for all project farmers.
- Agronomy package of practices manual for field staff / extension workers.
- Short video on various aspects of sugarcane development.

**Training and capacity building of extension workers and farmer training oversight:**

This is the main component of the project design. A detailed annual training calendar has been prepared for training the extension workers. Using well-renowned sugarcane experts, the project undertakes a holistic training for the extension workers not only on sugarcane agronomy, but also on soft issues such as communication, farmer mobilisation, motivation, grievance handling. Training is both in the classrooms as well as in the farmer fields. Detailed feedback is taken from every training participant after every session to make any changes, if required to the training design and delivery. Training of the field staff is imparted each month.

The project provided comprehensive oversight to the trained extension workers on farmer training. Detailed logbooks are maintained for every farmer selected under the project for all training activities as well as for activities undertaken on the farm (input record keeping, practices undertaken, time and date of practices etc.).

Using IFC’s global expertise in training and capacity building, a farmer flipchart has been developed under the project. The flipchart is a monthly calendar for farmers, in local vernacular, with illustrations of the practices to be performed on the field in that particular month. The flipchart has been developed after seeking inputs from IFC’s in-house ‘adult-education’ specialists who specialise in training design and delivery. Training to each farmer is imparted thrice in a year i.e. during autumn planting, spring planting, and summer for crop husbandry and plant protection.

**Independent baseline and evaluation of project performance:**

The project has instituted an independent mechanism for baseline assessment and evaluation of the project performance on a periodic basis through services of external, third-party consultants. The project has built in a quasi-experimental design to evaluate performance by comparing performance of ‘treatment farmers’ (those receiving project services) with a statistically selected ‘matched control farmers’ (those not receiving project services). Using statistical tools such as quasi-experimental evaluation design which allows a comparison of the performance of the treatment and control farmers, one is able to establish causality and attribution of the project on farmer performance.

The project has a focus on working with smallholders. For the initial pilot of 2000 farmers, more than 50% of farmers are small and medium landholders with average land-holding between 2 to 5 hectares of land. For the scale-up project (12 000 farmers), 85% of the farmers are small (with up to 2 hectares of land).

The social classification of the farmers is known from the focus groups carried out with farmers in all four mill areas. Close to two thirds of farmers in the area are from general caste category and about one fifth are from Other Backward Castes (OBCs) and the rest belong to Scheduled Castes (SC).

It may be noted that quite a number of farmers are from marginalised social communities in the area. In terms of education profile, the focus groups discussion shows that close to half of the farmers in the area are illiterate and cannot read and write. About one third are educated up to primary or secondary while the rest about one tenth are graduate and above.

Agriculture is the main source of livelihoods for the families surrounding the four mill areas. For most of these farmers, the main crop cultivated is sugarcane, followed by potato, vegetables, wheat and paddy. However, as was evident in the case of DSCL (Sugar), there was an increasing tendency among farmers, especially small and marginal, to switch from sugarcane to other competing crops on account of low returns from sugarcane (due to low yields).

Most sugar companies in Uttar Pradesh had reported a declining trend in sugarcane acreage in their command area despite acceleration in the company’s extension efforts.
The key cane development activities undertaken in the project are as follows:

- Propagation of improved varieties (e.g. seed program)
- Modern planting techniques (e.g. trench planting, inter-cropping with cane)
- Nutrition management (e.g. balanced fertiliser application, organic manure, farm-yard manure)
- Ratoon management (e.g. harvesting from the ground level, early application of fertilisers, gap filling)
- Good irrigation practices (e.g. furrow irrigation, small-bed irrigation) as compared to whole field flood irrigation

Results and discussions

For the pilot of 2000 farmers, an independent endline survey, in conjunction with the crop-cutting survey, was conducted for randomly selected matched pairs for 135 project/treatment farmers and 85 control farmers across groups.

The results of cane yield based on crop cutting of project farmers in comparison to baseline are summarised in Tables 1(A), 1(B) and Figure 1. These results built a business case for IFC and DSCL (Sugar) to scale-up the program to cover an additional 12 000 farmers.

<table>
<thead>
<tr>
<th>No</th>
<th>Typologies of Crops (BL-EL)</th>
<th>Yield (Tonnes per hectare)</th>
<th>BASELINE (BL)</th>
<th>ENDLINE (EL)</th>
<th>% Change</th>
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<tr>
<td></td>
<td>Nos.</td>
<td>Avg. Yield</td>
<td>Min</td>
<td>Max</td>
<td>SD</td>
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<tr>
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<td>Plant-plant</td>
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<td>49.96</td>
<td>25.60</td>
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<tr>
<td>2</td>
<td>Ratoon-Ratoon</td>
<td>80</td>
<td>44.53</td>
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<tr>
<td></td>
<td>Overall</td>
<td>132</td>
<td>46.41</td>
<td>12.80</td>
<td>87.80</td>
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<th>No</th>
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<th>BASELINE (BL)</th>
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<td>2</td>
<td>Ratoon-Ratoon</td>
<td>34</td>
<td>44.51</td>
<td>30.80</td>
<td>94.40</td>
</tr>
<tr>
<td></td>
<td>Overall</td>
<td>85</td>
<td>49.58</td>
<td>29.00</td>
<td>94.40</td>
</tr>
</tbody>
</table>

It may be observed that:

- At the end line of the project in year two, the average yield of plant crop for project/treatment farmers increased from 49.96 to 94.24 tonnes per hectare (89%) over two years whereas the yield of plant crop has increased from 44.54 tonnes to 81.61 tonnes per hectare (83%) compared to the baseline. The overall average yield of plant and ratoon crop of both the mills increased from 46.41 tonnes to 86.58 tonnes per hectare (87%).
In the second year, the overall yield of the control group of farmers also increased from 52.75 tonnes to 62.85 tonnes per hectare (19%) in both mills put together. The increase in yield of ratoon and plant crop was almost the same at about 18% and 19 per cent, respectively. The sharp increase in yield for ratoon crop is on expected lines as the ratoon crop is usually neglected by farmers.

In this study, it was interesting to note that in the first year the overall yield of sugarcane of treatment farmers increased by 23 per cent, whereas the yield of control farmers declined by about 11% as compared to the base line. However, in the second year the yield of project farmers increased by 87% and the yield of control farmers also increased by 19 per cent. The higher increase in yield by project farmers is attributed to the capacity building through training resulting in accelerated adoption of the agronomy package of practices on the ground by a large number of project farmers as may be seen from the data given in Table 2 and Table 3.

The decline in yield of control farmers in the first year is attributed to seasonal variation and higher incidence of top borer due to lack of correct knowledge for top-borer protection. In the second year, there was a lot of ‘contamination in the sample’ during the training and implementation as control farmers also took lessons from the project farmers and some of them adopted the agronomy package after seeing the results of project farmers in the first year.

![Sugarcane average productivity yield (baseline and endline)](image)

**Fig. 1—Sugarcane average productivity yield (baseline and endline).**

**Attribution of results to on-ground activities**

Knowledge increase for farmers from the package of practices as a result of training and capacity building is mentioned in Table 2. Area covered under various agronomic practices in both sugar mills is given in Table 3.

One of the prime reasons for conducting a quasi-experimental evaluation for the project was to establish causality and adduce attribution of the outcomes to project activities.
Table 2—Package of practices – extent of correct knowledge by project farmers.

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Package of Practice</th>
<th>Baseline</th>
<th>Endline</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Field preparation done correctly</td>
<td>83%</td>
<td>95%</td>
</tr>
<tr>
<td>2.</td>
<td>Fertiliser application during sowing</td>
<td>77%</td>
<td>92%</td>
</tr>
<tr>
<td>3.</td>
<td>Autumn planting</td>
<td>49%</td>
<td>100%</td>
</tr>
<tr>
<td>4.</td>
<td>Trench planting</td>
<td>48%</td>
<td>63%</td>
</tr>
<tr>
<td>5.</td>
<td>Fertiliser – knows balanced utilisation</td>
<td>34%</td>
<td>90%</td>
</tr>
<tr>
<td>6.</td>
<td>Understanding of role of micro-nutrients</td>
<td>41%</td>
<td>78%</td>
</tr>
<tr>
<td>7.</td>
<td>Early shoot borer eradication – farmer knows exactly</td>
<td>57%</td>
<td>86%</td>
</tr>
<tr>
<td>8.</td>
<td>Termite control – farmer knows exactly</td>
<td>56%</td>
<td>57%</td>
</tr>
<tr>
<td>9.</td>
<td>Shoot borer – farmer knows exactly</td>
<td>48%</td>
<td>81%</td>
</tr>
<tr>
<td>10.</td>
<td>Follow productive irrigation</td>
<td>61%</td>
<td>96%</td>
</tr>
<tr>
<td>11.</td>
<td>Fertiliser application irrigation</td>
<td>45%</td>
<td>84%</td>
</tr>
<tr>
<td>12.</td>
<td>Farmer knows about gap filing</td>
<td>29%</td>
<td>61%</td>
</tr>
<tr>
<td>13.</td>
<td>Sugarcane trash as soil mulch</td>
<td>75%</td>
<td>84%</td>
</tr>
<tr>
<td>14.</td>
<td>Fertiliser application – knows correctly</td>
<td>28%</td>
<td>77%</td>
</tr>
<tr>
<td>15.</td>
<td>Harvesting – knows correct method and application</td>
<td>39%</td>
<td>99%</td>
</tr>
</tbody>
</table>

Table 3—Area (hectares) covered under major sugarcane development activities in Mill 1 and Mill 2.

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Activity Name</th>
<th>MILL 1</th>
<th>MILL 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Planting</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a)</td>
<td>Autumn planting</td>
<td>94</td>
<td>99</td>
</tr>
<tr>
<td>(b)</td>
<td>Spring planting</td>
<td>764</td>
<td>566</td>
</tr>
<tr>
<td>(c)</td>
<td>Inter crop</td>
<td>77</td>
<td>89</td>
</tr>
<tr>
<td>(d)</td>
<td>Trench planting</td>
<td>148</td>
<td>123</td>
</tr>
<tr>
<td>(e)</td>
<td>Early varieties</td>
<td>109</td>
<td>149</td>
</tr>
<tr>
<td>(f)</td>
<td>New, improved varieties</td>
<td>6</td>
<td>23</td>
</tr>
<tr>
<td>2.</td>
<td>Balanced manure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a)</td>
<td>Organic manure/press mud</td>
<td>166</td>
<td>389</td>
</tr>
<tr>
<td>(b)</td>
<td>Neem cake</td>
<td>210</td>
<td>372</td>
</tr>
<tr>
<td>(c)</td>
<td>NPK complete dose on time</td>
<td>1039</td>
<td>779</td>
</tr>
<tr>
<td>(d)</td>
<td>Micro-nutrients</td>
<td>310</td>
<td>298</td>
</tr>
<tr>
<td>(e)</td>
<td>Zinc sulfate</td>
<td>283</td>
<td>309</td>
</tr>
<tr>
<td>(f)</td>
<td>Foliar spray</td>
<td>226</td>
<td>516</td>
</tr>
<tr>
<td>(g)</td>
<td>Top dressing by June</td>
<td>664</td>
<td>504</td>
</tr>
<tr>
<td>3.</td>
<td>Ratoon Management</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a)</td>
<td>Stubble shaving</td>
<td>240</td>
<td>250</td>
</tr>
<tr>
<td>(b)</td>
<td>Gap filling</td>
<td>56</td>
<td>25</td>
</tr>
<tr>
<td>(c)</td>
<td>Trash mulching</td>
<td>194</td>
<td>94</td>
</tr>
<tr>
<td>(d)</td>
<td>Off barring</td>
<td>203</td>
<td>163</td>
</tr>
<tr>
<td>4.</td>
<td>Irrigation (6 timely applications)</td>
<td>488</td>
<td>761</td>
</tr>
<tr>
<td>5.</td>
<td>Plant Protection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a)</td>
<td>Seed treatment</td>
<td>373</td>
<td>329</td>
</tr>
<tr>
<td>(b)</td>
<td>Soil treatment</td>
<td>207</td>
<td>283</td>
</tr>
<tr>
<td>(c)</td>
<td>Top borer control</td>
<td>174</td>
<td>319</td>
</tr>
<tr>
<td>(d)</td>
<td>Smut Roguing</td>
<td>7</td>
<td>42</td>
</tr>
<tr>
<td>(e)</td>
<td>ESB Roguing</td>
<td>161</td>
<td>472</td>
</tr>
<tr>
<td>6.</td>
<td>Crop Husbandry</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a)</td>
<td>Inter culture operations</td>
<td>443</td>
<td>295</td>
</tr>
<tr>
<td>(b)</td>
<td>Earthing-up</td>
<td>15</td>
<td>59</td>
</tr>
<tr>
<td>(c)</td>
<td>Propping up</td>
<td>15</td>
<td>134</td>
</tr>
</tbody>
</table>

Note: In 2nd Year, major variety Co.S.92423 has been deleted from the program due to low sugar content, resulting in the overall low acreage, although percentage coverage is higher.
The causality for enhanced productivity has been attributed to the following parameters, based on the following regression analysis:

- Social status of the farmer
- Training programs / capacity building / exposure to farmers
- Of these two significant factors (Table 4), the project had the greatest influence in the training and capacity building of farmers, where as discussed before, all effort was made to ensure effective transfer of knowledge and practices to farmers. The training programs were designed with ‘adult education’ principles in mind, following instructional design that is mostly suited for illiterate farmers (such as pictorial flipcharts) and in local vernacular.

<table>
<thead>
<tr>
<th>Factors</th>
<th>Indicators</th>
<th>Coefficient value</th>
<th>Standard error</th>
<th>T value</th>
<th>Significance value</th>
<th>Statistical significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Social status of the farmer</td>
<td>Farmer social category</td>
<td>0.105</td>
<td>0.024</td>
<td>17.601</td>
<td>0.031</td>
<td>Significant</td>
</tr>
<tr>
<td>Literacy level of respondent in the household</td>
<td>Education level of the respondent in the household</td>
<td>–0.070</td>
<td>0.024</td>
<td>13.582</td>
<td>0.150</td>
<td>Not significant</td>
</tr>
<tr>
<td>Literacy level of females in the household</td>
<td>Education level of the females in the household</td>
<td>–0.015</td>
<td>0.061</td>
<td>–60.235</td>
<td>0.761</td>
<td>Not significant</td>
</tr>
<tr>
<td>Training programmes / capacity building / exposure to farmers</td>
<td>Training programs on sugarcane BMPs, and access to demonstration plots</td>
<td>0.185</td>
<td>0.024</td>
<td>19.691</td>
<td>0.030</td>
<td>Significant</td>
</tr>
<tr>
<td>Economic status of the household</td>
<td>BPL card-holder or not</td>
<td>0.089</td>
<td>0.011</td>
<td>0.000</td>
<td>0.069</td>
<td>Not significant</td>
</tr>
<tr>
<td>Status of farmer's house</td>
<td>Condition of farmer's house (Pucca, semi-pucca or kutcha house)</td>
<td>0.070</td>
<td>0.022</td>
<td>9.436</td>
<td>0.151</td>
<td>Not significant</td>
</tr>
<tr>
<td>Self land-holding of the farmer</td>
<td>Own land or leased</td>
<td>0.010</td>
<td>0.987</td>
<td>–13.284</td>
<td>0.844</td>
<td>Not significant</td>
</tr>
<tr>
<td>Status of irrigation facilities at the farm</td>
<td>Availability of assured irrigation for sugarcane</td>
<td>0.044</td>
<td>0.012</td>
<td>–70.365</td>
<td>0.365</td>
<td>Not significant</td>
</tr>
<tr>
<td>Member of learning groups</td>
<td>Training on sugarcane agronomy</td>
<td>–0.011</td>
<td>0.002</td>
<td>–4.477</td>
<td>0.815</td>
<td>Not significant</td>
</tr>
<tr>
<td>Information source for technical inputs to increase productivity</td>
<td>Information source for sugarcane farming</td>
<td>–0.066</td>
<td>0.017</td>
<td>4.428</td>
<td>0.174</td>
<td>Not significant</td>
</tr>
<tr>
<td>Level of access to credit by farmers for agri-loans through the government</td>
<td>Loans accessed (%) from Kisan Credit Card</td>
<td>–0.024</td>
<td>0.024</td>
<td>15.201</td>
<td>0.618</td>
<td>Not significant</td>
</tr>
<tr>
<td>Level of access to credit by farmers for agri-loans through other sources</td>
<td>Loans accessed (%) from MFI and other sources</td>
<td>–0.020</td>
<td>0.024</td>
<td>18.243</td>
<td>0.689</td>
<td>Not significant</td>
</tr>
</tbody>
</table>

Location – Ajbapur and Loni (endline productivity; treatment farmers)
Number of farmers in the sample – 421

**Enhanced incomes**

Under this project, on an average the project farmers have benefited through additional incomes as a result of an increase in farm yields, as illustrated in Table 5. At the sugarcane price for Year 2009–10 at INR 1600 (or USD 32) per tonne (project start date), the (net) incomes for farmers have increased from around INR 9240 (or USD 190) to INR 61 000 (or USD 1200) per hectare as compared to the baseline.
At current sugarcane prices INR 2400 (or USD 48) per tonne (2011–12), the (net) income increase is even more substantial at over INR 130 000 (or USD 2600) per hectare. Farm incomes and cash flows have increased even further through inter-cropping resulting in a net per hectare additional benefit of INR 68 000 (or USD 1360) from potato and INR 15 000 (or USD 300) from mustard on an average. Since yields for control farmers are lower than those for project farmers, there is a difference in the incomes from sugarcane for control farmers as compared to project farmers.

Table 5—Increase in Income (Net) for Mitha Sona farmers from increased yields.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Treatment</td>
<td>Control</td>
</tr>
<tr>
<td>1</td>
<td>Yield (t/ha)</td>
<td>46.40</td>
<td>49.57</td>
</tr>
<tr>
<td>2</td>
<td>Baseline Price (INR per tonne)</td>
<td>1600</td>
<td>1600</td>
</tr>
<tr>
<td>3</td>
<td>Gross Income (INR per hectare)</td>
<td>74 240</td>
<td>79 312</td>
</tr>
<tr>
<td>4</td>
<td>Average Cost of Production (INR per hectare)</td>
<td>65 000</td>
<td>65 000</td>
</tr>
<tr>
<td>5</td>
<td>Net Income (INR per hectare)</td>
<td>92 40</td>
<td>14 312</td>
</tr>
</tbody>
</table>

Net Income (INR) at Endline Prices

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Treatment</td>
<td>Control</td>
</tr>
<tr>
<td>1</td>
<td>Yield (t/ha)</td>
<td>46.40</td>
<td>49.57</td>
</tr>
<tr>
<td>2</td>
<td>Baseline Price (INR per tonne)</td>
<td>2400</td>
<td>2400</td>
</tr>
<tr>
<td>3</td>
<td>Gross Income (INR per hectare)</td>
<td>111 360</td>
<td>118 968</td>
</tr>
<tr>
<td>4</td>
<td>Average Cost of Production (INR per hectare)</td>
<td>65 000</td>
<td>65 000</td>
</tr>
<tr>
<td>5</td>
<td>Net Income (INR per hectare)</td>
<td>46 360</td>
<td>53 968</td>
</tr>
</tbody>
</table>

Conclusion and lessons

On the basis of the strategy adopted and results obtained in the Mitha Sona Pariyojana, implemented jointly by IFC and the sugar company, it may be concluded that that the correct art of sugarcane development involving the following steps is effective in enhancing productivity and quality of sugarcane:

- Detailed diagnostic study of the command area of sugar mills.
- Formulation of tailor-made action plan / road map on the basis of findings of diagnostic study suit local conditions and socio-economic environment.
- Designing of training modules and imparting training to the extension workers of the sugar mills in an effective manner to enable them to educate / motivate / convince farmers to adopt correct techniques of sugarcane cultivation.
- Close monitoring of implementation of each and every aspect of the sugarcane development plan to ensure correct implementation of the program on the ground.

A successful farmer training and capacity building / extension program must have the following as guiding principles: Suitability, Sustainability and Scalability as described in Figure 2.

- **Suitability**: The suitability or relevance of the project is an integral component of the project design. Sugarcane is a crop that is affected by regional variations in agro-climatic, soil and varietal conditions. Therefore, the agronomy package of practices has to be customised and tailor-made, to the extent required, suit the local agro-climatic conditions. Similarly, any uptake of the package of practices by farmers depends on the socio-economic conditions of the farmers. These contextual and spatial nuances have been kept in mind while designing the components of the project. For instance, keeping in mind the constraint of labour shortages for sugarcane and a provision for custom-hire services for field preparation through mechanised trench planting have been included in the recommended package of practices. Similarly, for popularising trench planting, the company provided attractive incentives to the farmers to accelerate adoption.
Fig. 2—Steps for designing a training and capacity building program.

- **Sustainability:** Sustainability of the initiative, after the end of the pilot project, is an integral component of the project design. For instance, the project works through the capacity building of the extension workers of the company. These extension workers are part of the company’s workforce and are the ‘face’ of the company to the farmers. The interactions that these extension workers have with the farmers on a regular basis, if managed well, can go a long way in building the relationship between the company and the farmers.

- **Scalability:** The ultimate aim of the project is to demonstrate a successful model for sugarcane development that any sugar mill can scale-up to a large number of farmers in their supply-chain. Towards this end, the project built in several factors such as working with progressive and influential farmers (as treatment farmers) to start with. These ‘opinion-making’ farmers are the ones who are the most responsive to change and adopt new practices. These farmers also have the influencing power in their respective communities to influence other farmers to adopt similar practices on their farms. Thus, the ‘ripple-effect’ of the select group of treatment farmers is much wider in the supply-chain, as these farmers act as ‘catalysts’ and ‘agents of change’ in their respective communities.

**Acknowledgements**

IFC acknowledges DSCL and the sugarcane farmers in the supply-area of DSCL for making the Mitha Sona Pariyojana a success.

**REFERENCES**


**IFC Disclaimer:** This paper may contain advice, opinions, and statements of various information providers and content providers. IFC does not represent or endorse the accuracy or reliability of any advice, opinion, statement or any other information provided by any information provider, or content provider, or any user of this paper or other person or entity.

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**AMELIORER LA PRODUCTIVITE DES PETITS EXPLOITANTS EN INDE PAR LE RENFORCEMENT DES CAPACITES DES AGENTS DE VULGARISATION**

Par

HARSH VIVEK et RAJ PAL SINGH

*International Finance Corporation (IFC), New Delhi, Inde*

[harshviv@gmail.com, hvivek@ifc.org](mailto:harshviv@gmail.com, hvivek@ifc.org)

**MOTS-CLÉS:** Productivité des Petits Exploitants, Renforcement des Capacités, Services de Vulgarisation.

**Résumé**

Le ‘MITHA SONA PARIYOJANA’ (ou le programme *Sweet Gold*), projet ayant pour objectif l’amélioration de la productivité des fermes de canne à sucre, a été mis en œuvre conjointement par l’IFC et le DSCL (sucré) dans l’Uttar Pradesh au nord de l’Inde. C’est une tentative d’utiliser le pouvoir du secteur privé pour faire face au défi de la productivité dans la chaîne de valeur sucrière dans le but général d’améliorer les revenus agricoles. Les cultivateurs de canne à sucre, en particulier dans des états tels l’Uttar Pradesh et le Bihar, continuent à faire face aux défis pour améliorer les revenus agricoles en raison des faibles rendements aux champs dus à la prédominance des petites exploitations marginales, à l’agriculture de subsistance, et à un ensemble de pratiques agronomiques médiocres. Le programme renforce les capacités des agents de vulgarisation du DSCL afin d’améliorer la vulgarisation agricole et la formation des agriculteurs pour amener à une meilleure productivité. L'évaluation indépendante de la performance du projet sur un échantillon aléatoire de combinaison de paires entre les agriculteurs participant au projet et ceux du contrôle démontre une augmentation moyenne, sur les niveaux de productivité de base, de 23 pour cent dans le rendement des agriculteurs du projet pour la première année et de 87 pour cent pour la deuxième année. Fait intéressant, pour la première année, le rendement des agriculteurs de contrôle a diminué de 11 pour cent en raison d'une attaque de foreurs de tiges tandis que, pour la deuxième année, une augmentation de rendement de 19 pour cent a été enregistrée, même pour les agriculteurs de contrôle, en raison de l'adoption de l'ensemble des mesures agronomiques par certains de ces agriculteurs après qu’ils aient constaté les résultats des agriculteurs participant au projet. La majorité des agriculteurs concernés par le projet sont de petits exploitants dont les champs sont en moyenne d’environ 2 hectares.
MEJORANDO LA PRODUCTIVIDAD DE LOS PEQUEÑOS PRODUCTORES DE INDIA A TRAVÉS DE LA CAPACITACIÓN DE LOS TECNICOS EXTENSIONISTAS DE CAMPO

Por

HARSH VIVEK y RAJ PAL SINGH

International Finance Corporation (IFC), New Delhi, India

harshviv@gmail.com, hvivek@ifc.org

PALABRAS CLAVE: Pequeños Productores, Mejora de la Capacidad, Servicios de Extensión en Campo.

Resumen

EL PROGRAMA ‘MITHA SONA PARIYOJANA’ (Oro Dulce) es un proyecto de mejora de la producción de caña de azúcar en campo implementado en Uttar Pradesh, región norte de India por IFC y DSCL (Azúcar) y es un intento de usar el potencial del sector privado para atender el reto de productividad en la cadena de valor del azúcar. Este programa fue establecido con el objetivo general de mejorar los ingresos de los pequeños productores. Los agricultores de caña de azúcar de estados como Uttar Pradesh y Bihar siguen enfrentando retos para mejorar sus ingresos por la baja productividad que se debe en gran parte a que sus pequeñas propiedades tienen suelos marginales donde emplean prácticas de agricultura muy pobre, enfocada solo en la subsistencia. El programa mejora la capacidad del personal extensionista de DSCL, para fortalecer el entrenamiento de los agricultores para que logren mejorar la productividad. Se realizó una evaluación independiente del desempeño de a una muestra de agricultores en el proyecto y agricultores en el grupo control. Para los agricultores en un proyecto se determinó un incremento promedio de 23 por ciento en la productividad para el primer año y de 87 por ciento para el segundo año, comparando con un valor base de productividad. Los agricultores en el grupo control, sufrieron una baja en la productividad durante el primer año debido al ataque de barrenador de las puntas, mientras en el segundo año, obtuvieron un incremento promedio de 19 por ciento en la productividad. Esto se debió a la adopción de paquetes agronómicos por parte de algunos, después de ver los resultados de los agricultores participantes en el proyecto. La mayor parte de los agricultores en el proyecto son productores a pequeña escala dueños de lotes de alrededor de 2 hectáreas en promedio.
MELHOR ANDO A PRODUTIVIDADE DE PEQUENOS PRODUTORES NA ÍNDIA PELA CAPACITAÇÃO DE SUPERVISORES DE CAMPO

Por

HARSH VIVEK e RAJ PAL SINGH

International Finance Corporation (IFC), New Delhi, Índia
harshviv@gmail.com, hvivek@ifc.org

PALAVRAS-CHAVE: Produtividade de Pequenas Propriedades, Capacitação, Serviços de Extensão ao Campo.

Resumo

O “MITHA SONA PARIYOJANA” (ou Progama Doce Ouro), um projeto de de melhoria de produtividade em uma propriedade produtora de cana, implementado conjuntamente pela IFC e a DSCL (Sugar) em Uttar Pradesh ao norte da Índia, é uma tentativa de usar o poder do setor privado para tratar do desafio de produtividade na cadeia de valor do açúcar com o objetivo geral de aumentar as rendas das propriedades. Os produtores de cana, especialmente em estados como Uttar Pradesh e Bihar, continuam a enfrentar desafios para melhorar suas rendas resultantes de baixas produtividades agrícolas devido a uma estrutura fundiária de propriedades pequenas ou marginais e agricultura de subsistência, além de práticas agronômicas precárias. O programa capacita supervisores de campo do DSCL para fortalecer a extensão da propriedade e o treinamento do produtor para aumentar a produtividade. A avaliação independente do desempenho do projeto para uma amostra aleatória de pares combinados dos produtores do Projeto/tratamento e produtores de controle indica um aumento médio de 23 por cento na produtividade de produtores do tratamento no primeiro ano e 87 por cento no segundo ano em relação aos níveis de referência de produtividade. Curiosamente, no primeiro ano, a produtividade os produtores do controle diminuiu cerca de 11 por cento devido a um ataque de brocas, ao passo que, no segundo ano, a produtividade média aumentou 19 por cento mesmo para os produtores de controle devido à adoção de um pacote agrícola por alguns dos produtores de controle após constatarem os resultados dos produtores do projeto. A maioria dos produtores cobertos pelo projeto são pequenos proprietários com propriedades de cerca de 2 hectares.
THE VARIABILITY AND DRIVERS OF THE CARBON FOOTPRINT OF CANE SUGAR

By

J. FISHER
Tate & Lyle Process Technology
jack.fisher@asr-group.com

KEYWORDS: Carbon Footprint, Monte Carlo Simulation.

Abstract

The carbon footprint (GHG emissions) of sugar is of increasing interest to sugar users and consumers. This study considers the potential variability on a global basis of the carbon footprint of cane sugar, and investigates the key drivers affecting this variability. A mathematical model was built to represent the production of sugar from field to market. Key input values were replaced by ranges to reflect the variability and uncertainty associated with the diversity of sugar production scenarios worldwide. Monte Carlo simulation was carried out to simulate the effect of these variations on the model outputs, which were assessed against the Bonsucro method (with modifications and additions) for estimating GHG emissions. The carbon footprint of field-to-gate raw sugar ranged between 217 and 809 g CO\textsubscript{2eq} per kg sugar in 90% of simulations. The biggest drivers were the country of origin, agricultural methods, power production/export and process energy efficiency. Production of plantation white sugar and transport to a local market added another 100–150 g CO\textsubscript{2eq}/kg, split between transport and processing emissions. The carbon footprint of field-to-market factory-refined sugar ranged between 329 and 1121 g CO\textsubscript{2eq}/kg. The increase from raw sugar was mainly due to increased fossil fuel usage, and the biggest driver was process energy efficiency. The carbon footprint associated with shipping raw sugar from port, refining at a destination refinery, and transporting to market ranged between 465 and 660 g CO\textsubscript{2eq}/kg. The biggest driver was refinery energy efficiency. Finally, the carbon footprint of field-to-market destination-refined sugar ranged between 621 and 1459 g CO\textsubscript{2eq}/kg in 90% of simulations, of which the distance from factory to port was an additional significant driver. The potential variability in cane sugar carbon footprint has been shown to be large, depending on where and how it is produced. However, by focusing on areas such as irrigation, agricultural chemicals, cane yields, power generation and export, process energy efficiency and cane burning, it is realistic to achieve a negative carbon footprint for field-to-market refined sugar: a net emissions credit of 260 g CO\textsubscript{2eq}/kg was simulated, improving to 565 g CO\textsubscript{2eq}/kg with trash recovery and to 1470 g CO\textsubscript{2eq}/kg with biomass gasification.

Introduction

The GHG emissions resulting from production of sugar in the context of global warming are of increasing interest and importance to consumers. This impact is most appropriately measured via the estimation of the overall greenhouse gas (GHG) emissions resulting from sugar production, or its ‘carbon footprint’. A growing number of manufacturers and retailers are estimating and publicly stating the carbon footprint associated with various products, including beet and cane sugar, while consumer awareness is likely to create pressure on more cane sugar manufacturers, refiners and retailers to publish similar information. This paper has the following aims:

1. To estimate the potential global variability in carbon footprint of cane sugar.
2. To identify the key drivers affecting this variability.
3. To explore the potential for manipulating these drivers to minimise carbon footprint.

Five scenarios were investigated in this study:
- Scenario 1: Field-to-factory-gate raw sugar.
- Scenario 2: Field-to-market plantation white sugar.
- Scenario 3: Field-to-market refined sugar (refinery annexed to factory).
- Scenario 4: Raw sugar port to refined sugar market (i.e. raw sugar transport and refining).
- Scenario 5: Field-to-market refined sugar (refinery separate from factory).

Following these investigations, three further scenarios were modelled to investigate the potential to achieve low-emissions refined sugar:
- Scenario 6: Low emissions refined sugar.
- Scenario 7: Very low emissions refined sugar.
- Scenario 8: Extremely low emissions refined sugar.

Method of analysis

Modelling

Estimation of the carbon footprint involved firstly creating a model of the system under analysis. This was carried out using SugarCaneModel, a technical and economic modelling tool for the cane sugar industry. SugarCaneModel builds mass and energy balances for the processes and utilities involved, i.e. agriculture, raw sugar processing, ethanol production, sugar refining, steam/power production, and transport.

A key feature of SugarCaneModel is that it allows the modelling of uncertainty via Monte Carlo simulation methods. Monte Carlo simulation can be described simplistically as incorporating three steps:

1. Replace any model input parameter which is subject to inherent uncertainty with a range of values represented by a probability distribution.
2. Recalculate the model over and over again, each time using a different set of random inputs as sampled from the probability distributions.
3. Aggregate the results from each recalculation and generate probability distributions for each output value.

Monte Carlo simulation provides two key benefits. Firstly, and most importantly, it provides a range of outcomes from which the probability that they will occur can be calculated. This contrasts with traditional static modelling, in which fixed input values give a single fixed output value. In a world dominated by variability and uncertainty, this fixed output reflects only one of a myriad of possible outcomes. Secondly, it provides transparency for the key input parameters driving the variability of the outputs, via sensitivity analysis. These characteristics of Monte Carlo simulation are ideally suited to this study, which is aiming to analyse variability across a diverse range of scenarios, and to identify the key drivers.

In this study, key model inputs (listed in tables) were designated as being variable and replaced by probability distributions. Three different distribution types were used: discrete, PERT, and uniform. These distributions are described briefly.

Discrete distributions

Discrete distributions are simple: there are a finite number (typically two or three) of values that the input can take and the probability of each value occurring is defined. For example, in the model, the molasses produced from a sugar factory is either processed into ethanol or sold directly. The probability of the molasses being processed into ethanol was set at 30%. Therefore, for every 1000 simulations of the model, roughly 300 will involve a molasses distillery and, in the other 700, the molasses will be sold directly.
**Uniform distributions**

Uniform distributions are also simple, and are defined by two values: a minimum and a maximum. In a uniform distribution, there is an equal probability of any value occurring between the minimum and maximum. For example, in the model, the boiler steam pressure varies between 20 and 100 bar, with equal probability of any value in that range occurring.

**PERT distributions**

The most common distribution used in this study was the PERT distribution. PERT distributions are defined by three values: minimum, maximum, and most likely. For example, for irrigated fields, the water application was allowed to vary between 0 and 4000 mm, with a most likely value of 500. In a PERT distribution, there is a higher probability of values around the most likely value being selected, and a lower probability of values around the minimum and maximum. This is illustrated in Figure 1, which shows the actual probability distribution used in the model. The vertical axis represents probability.

![Fig. 1—PERT distribution example: irrigation water usage (mm).](image)

**Method of assessing GHG emissions**

The GHG emissions (carbon footprint) for various production systems were estimated by taking the outputs from SugarCaneModel and applying the method published and applied by Bonsucro (2011) to accredit sugar producers under the Bonsucro Certification System, the first global metric standard for sugarcane. The method (details can be obtained from the Bonsucro website) is a field-to-gate analysis which accounts for direct and indirect energy use and GHG emissions in the following areas:

- Agriculture (irrigation, chemical use, cane burning\(^1\), transport fuel use, field residues)
- Fossil fuels burnt
- Electricity imports/exports\(^2\)
- Process chemicals used
- Allocation to co-products (e.g. molasses, ethanol)

\(^1\) CH\(_4\) and N\(_2\)O emissions.
\(^2\) Export of electricity achieves a credit in terms of energy and emissions saved, according to the displacement of energy in that country. The Bonsucro method uses the grid average emissions to calculate the credit. There is an argument that this is conservative as in reality electricity exports are likely to replace marginal energy production, which is likely to be from fossil fuels. However, at present the Bonsucro method follows the EU Renewable Energy Directive in this respect.
In addition to the methodology and data published by Bonsucro, the following assumptions and data were used for GHG emissions estimation:

1. Transport of products was included (where applicable), with road transport assumed and diesel used as fuel.
2. Sea transport of raw sugar for refining was included (where applicable), with emissions factors from Defra (2011)\(^3\).
3. Emissions factors from electricity generation were taken from IEA (2011), with 2007–2009 averages used. IEA data were used as the range of countries included is wider than the range given in the Bonsucro standard. For destination refineries, the Bonsucro average (i.e. non-country-specific) emissions factor for electricity generation (150 g CO\(_{2}\)eq/MJ) was used.
4. Cane stalks left on the field after harvest contain 0.1% nitrogen, as stated after 12 months growth by Bakker (1999).
5. Cane trash (tops and leaves) left on the fields after harvest contains 0.5% nitrogen. This is an approximation from data from Pankhurst (2005) and Bakker (1999).
6. Filter mud returned to the fields contains 5% nitrogen on a dry basis, as stated by Smith-Baez (2008).
7. The concentration of CaCO\(_3\) in agricultural lime was assumed to be 65%.
8. Waste-water treatment and raw water intake was included, with emission factors from Defra (2011).\(^4\)
9. It is assumed that in none of the scenarios modelled was non-agricultural land converted to agricultural use after 1 January 2008.

**Scenario 1: Field-to-factory-gate raw sugar**

The first scenario modelled was raw sugar production. The model incorporated cane growing, harvest, transport to factory and production into raw sugar, molasses and/or ethanol. The GHG emissions were calculated on a cradle-to-gate basis, i.e. excluding any transport of raw sugar from the factory. 3000 model simulations were run, and the basis for each was 20 000 hectares of land. The same input dataset was used for each simulation, with selected inputs allowed to vary randomly from simulation to simulation according to defined probability distributions. The full input dataset is too lengthy to be reproduced here but is available on request. The variable inputs are listed in Tables 1 and 2. Table 1 contains the discrete variable inputs, while Table 2 contains the continuous variable inputs (for uniform or PERT distributions).

### Table 1—Variable (discrete) model inputs: field-to-factory-gate raw sugar.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value/range</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of simulations (non-Brazil) with irrigated fields</td>
<td>80%</td>
</tr>
<tr>
<td>% of simulations (Brazil) with irrigated fields</td>
<td>10%</td>
</tr>
<tr>
<td>% of simulations with irrigation via diesel pumps (i.e. not electric)</td>
<td>70%</td>
</tr>
<tr>
<td>% of simulations with cane trash recovered and used for additional fuel</td>
<td>2%</td>
</tr>
<tr>
<td>% of simulations with coal as supplementary fuel (remainder is fuel oil)</td>
<td>50%</td>
</tr>
<tr>
<td>% of simulations where power exported to grid (if available)(^5)</td>
<td>30%</td>
</tr>
<tr>
<td>% of simulations with some electrification of mill/preparation drives</td>
<td>40%</td>
</tr>
<tr>
<td>% of simulations with filter mud re-used on fields</td>
<td>80%</td>
</tr>
<tr>
<td>% of simulations with a distillery(^6)</td>
<td>30%</td>
</tr>
<tr>
<td>% of simulations with distillery vinasse processed in digestor for biogas production (remainder is applied to cane fields)</td>
<td>10%</td>
</tr>
</tbody>
</table>

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\(^3\) 5.7 gCO\(_{2}\)eq per tonne km for a 35 000–59 999 dwt bulk carrier, 55% loaded.

\(^4\) 0.70 gCO\(_{2}\)eq per kg wastewater and 0.34 gCO\(_{2}\)eq per kg raw water intake.

\(^5\) The country of origin varies according to the relative % of harvested area among the top 25 sugarcane producers according to 2010 data from FAO. For example, in 2010, Brazil harvested ~9 million ha, around 42% of the total from the top 25 producers. Therefore, in each simulation, there is a 42% probability that Brazil is the country of origin.

\(^6\) If trash recovered and used for fuel, then power is automatically exported

\(^7\) Otherwise, filter mud is disposed as a solid waste to landfill

\(^8\) If a distillery is included, then 100% of molasses is processed in the distillery into ethanol
Correlations were included in the model to link the variability of the fertiliser input parameters (N, P₂O₅ and K₂O required) and irrigation water usage with the variability in cane yield, i.e. if the irrigation water usage or fertiliser parameters varied upwards, the cane yield was likely to also vary upwards. Similar correlations were included to link imbibition water usage, mill extraction and bagasse moisture.

Results

Figure 2 shows the distribution of the results from the 3000 model simulations. The horizontal axis is the g CO₂eq/kg sugar, and the vertical axis represents frequency, i.e. there is a greater frequency of results around the 300–500 g region than lower or higher values. The chart shows that the mean carbon footprint was 441 g CO₂eq/kg sugar, and the median was 390. It shows that 90% of the simulations had carbon footprints between 217 and 809 g CO₂eq/kg sugar. A small number of simulations (0.5%) had negative carbon footprints, with 1% having values above 1200 g CO₂eq/kg sugar.

Table 2—Variable (continuous) model inputs: field-to-factory-gate raw sugar.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value/range</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cane yield (t/ha)</td>
<td>±25%¹</td>
<td>PERT</td>
</tr>
<tr>
<td>% of cane fields planted mechanically</td>
<td>20% (0–100%)</td>
<td>PERT</td>
</tr>
<tr>
<td>Litres of tractor fuel used per ha planted mechanically</td>
<td>35 (25–50)</td>
<td>PERT</td>
</tr>
<tr>
<td>Irrigation water usage (mm/y) – if fields irrigated</td>
<td>500 (0–4000)</td>
<td>PERT</td>
</tr>
<tr>
<td>Irrigation pumping head (m)</td>
<td>30 (20–50)</td>
<td>PERT</td>
</tr>
<tr>
<td>Irrigation diesel pump thermal efficiency</td>
<td>31% (26–35%)</td>
<td>PERT</td>
</tr>
<tr>
<td>Amount of nitrogen required as fertiliser (kg/ha)</td>
<td>75 (45–300)</td>
<td>PERT</td>
</tr>
<tr>
<td>Amount of P₂O₅ required as fertiliser (kg/ha)</td>
<td>90 (45–180)</td>
<td>PERT</td>
</tr>
<tr>
<td>Amount of K₂O required as fertiliser (kg/ha)</td>
<td>100 (50–200)</td>
<td>PERT</td>
</tr>
<tr>
<td>Amount of lime applied in the fields (kg/ha)</td>
<td>1000 (500–2000)</td>
<td>PERT</td>
</tr>
<tr>
<td>Amount of herbicide applied in the fields (kg/ha)²²</td>
<td>2.2 (1.1–3.3)</td>
<td>PERT</td>
</tr>
<tr>
<td>Pol % in cane stalk</td>
<td>14% (11–15%)</td>
<td>PERT</td>
</tr>
<tr>
<td>Fibre % in cane stalk</td>
<td>13.3% (11–15%)</td>
<td>PERT</td>
</tr>
<tr>
<td>Purity (sucrose) of cane stalk</td>
<td>90% (85–92.5%)</td>
<td>PERT</td>
</tr>
<tr>
<td>% of cane burnt prior to harvest</td>
<td>65% (0–100%)</td>
<td>PERT</td>
</tr>
<tr>
<td>% of trash recovered if trash recovery operated³²</td>
<td>50% (30–80%)</td>
<td>PERT</td>
</tr>
<tr>
<td>% of fields mechanically harvested</td>
<td>40% (0–100%)</td>
<td>PERT</td>
</tr>
<tr>
<td>Average distance from field to mill (km)</td>
<td>10 (1–20)</td>
<td>PERT</td>
</tr>
<tr>
<td>Mill sucrose extraction</td>
<td>95% (88–98%)</td>
<td>PERT</td>
</tr>
<tr>
<td>Mill imbibition water on fibre</td>
<td>200% (100–300%)</td>
<td>PERT</td>
</tr>
<tr>
<td>Bagasse moisture</td>
<td>50% (45–55%)</td>
<td>PERT</td>
</tr>
<tr>
<td>% of drives electrified in factories with electrification</td>
<td>75% (25–100%)</td>
<td>PERT</td>
</tr>
<tr>
<td>Energy usage in mill drives (kWh/te fibre)</td>
<td>83 (70–131)</td>
<td>PERT</td>
</tr>
<tr>
<td>Energy usage in cane preparation drives (kWh/te fibre)</td>
<td>67 (36–107)</td>
<td>PERT</td>
</tr>
<tr>
<td>Process energy efficiency</td>
<td>**</td>
<td>PERT</td>
</tr>
<tr>
<td>Boiling house process efficiency</td>
<td>**</td>
<td>PERT</td>
</tr>
<tr>
<td>Boiler steam pressure</td>
<td>20–100 bar</td>
<td>Uniform</td>
</tr>
<tr>
<td>Power generation turbine overall efficiency</td>
<td>70% (50–80%)</td>
<td>PERT</td>
</tr>
<tr>
<td>% of clear juice sent to distillery (if included)</td>
<td>50% (0–100%)</td>
<td>PERT</td>
</tr>
<tr>
<td>Ethanol yield in distillery fermentation (% of stoichiometric)</td>
<td>89% (88%–92%)</td>
<td>PERT</td>
</tr>
</tbody>
</table>

The variability of boiler house process efficiency is applied in the model via a Process Efficiency Factor. This factor was set at 5 and allowed to vary between 1 and 10. These values roughly correspond with a Boiler House Recovery (BHR) of 89% (varying between 84% and 92.5%), with the other inputs at average values.

¹ The cane yield varies with the country of origin, according to the average yields for 2010 from FAO data (e.g. Brazil average in 2010 was 70.4 t/ha). This value is then allowed to vary ±25%.
² If the filter mud and/or distillery vinasse is returned to the cane fields, their nutrients count against the required fertiliser components, i.e. the amount of fresh fertiliser required is reduced.
²² Herbicide is only applied if the trash blanket remaining on the fields after harvest is less than 7.5 t/ha
³ The variability of process energy efficiency is applied in the model via an Energy Efficiency Factor. This factor was set at 5 and allowed to vary between 1 and 10. These values roughly correspond with a factory process steam-on-cane of 45% (varying between 33% and 65%), with the other inputs at average values.
⁴ The variability of boiler house process efficiency is applied in the model via a Process Efficiency Factor. This factor was set at 2 and allowed to vary between 0.5 and 4. These values roughly correspond with a Boiler House Recovery (BHR) of 89% (varying between 84% and 92.5%), with the other inputs at average values.
The breakdown of the carbon footprint by category is illustrated by the table in Appendix 1, which shows the mean results for each of the scenarios. This shows that the majority of emissions result from the agricultural phase, with smaller amounts from cane transport (5–10%) and processing (15–20%). The total emissions due to cane production (up to the mill gate) are 630 g CO₂eq/kg sugar. The emissions due to electricity are shown as negative due to the average power export. The appropriate share of total emissions is allocated to co-products either by market value (for molasses) or by energy content (for ethanol). Of the agricultural emissions, the biggest contributor is nitrogen for fertilisation, followed by irrigation, cane burning and lime application. Of the processing emissions, the biggest contributors are caustic soda usage and bagasse burning.

**Comparison with other published carbon footprint estimates**
Comparing carbon footprint estimates from different sources is difficult due to the variability in methods used. Klenk *et al.* (2012) recently carried out a literature review of published carbon footprint estimations for cane sugar, only including estimates where the methodology was stated. Four estimates for raw sugar production (cradle-to-gate) were included, with values ranging between 210 and 550 g CO₂eq/kg sugar. One of those estimates was by Rein (2010), who developed the Bonsucro accounting method.

Rein’s estimate, 307 g CO₂eq/kg sugar, was based on a ‘typical’ sugar mill, producing sugar and molasses and exporting some power. As a method of validation, the model used in this paper was tested against the inputs used by Rein, with similar results. Rein (2011) later stated that values for raw sugar could be expected to be between 200 and 500 g CO₂eq/kg sugar, and more recently Rein (2012) cited various estimates between 203 and 800 g CO₂eq/kg sugar. One of those estimates was by Rein (2010), who developed the Bonsucro accounting method.

Figure 2 shows similarity to these previous published estimates. The 90% band is similar to the 203–800 range reported by Rein (2012). The mean and median are higher than Rein’s 2010 estimate of 307 g CO₂eq/kg sugar. In fact, three quarters of the simulations resulted in values above 307 g CO₂eq/kg sugar. Around two thirds of the simulations resulted in values within the 200–500 range suggested by Rein (2011) and reported by Klenk *et al.* (2012).

Renouf *et al.* (2010) assessed the carbon footprint of Australian sugarcane production based on data from the state of Queensland, with Monte Carlo simulation to account for variability. In 95% of cases, the carbon footprint was between 66.4 and 114.5 kg CO₂ per tonne cane delivered to
mill. At an assumed sugar yield (kg raw sugar per kg cane) of 12.5%, this equates to 531 to 916 g CO₂eq/kg sugar. The mean emissions from Appendix 1 are 630 g CO₂eq/kg sugar, i.e. within that range.

**Sensitivity analysis**

Figure 3 shows the top-ranked variable inputs in terms of the effect their variability had on the overall carbon footprint, i.e. it shows which inputs the carbon footprint was most sensitive to. The horizontal bars give an indication of the magnitude of the changes in carbon footprint caused by variations in each input. For example, variations in the cane yield caused the carbon footprint to fluctuate over a range of around 160 g CO₂eq/kg sugar. It should be noted that the sensitivity is a result of the importance of the parameter and the variability assigned to it (see Table 2).

![Fig. 3—Sensitivity analysis: field-to-factory-gate raw sugar.](image)

The key drivers as shown in Figure 3 are in the areas of agriculture (cane yield, irrigation and fertilisation), power production/export and process energy efficiency. The top-ranked input is the country of origin, which causes a number of impacts in the model:

(a) it affects the likely cane yield,
(b) it affects the likelihood of irrigation (in the case of Brazil), and
(c) it affects the GHG emissions credit allocated to power export (see the Bonsucro standard for more detail).

The presence of trash recovery efficiency is interesting, as trash recovery was only carried out in 2% of simulations. This indicates the potential importance of trash recovery, which is explored further in scenarios 7 and 8.

**Scenario 2: Field-to-market plantation white sugar**

The second scenario modelled was the production of plantation white sugar, including product transport (sugar, molasses and ethanol) to market. Plantation white sugar is here defined as white sugar produced in a sugar factory (as distinct from ‘refined’ sugar) and intended for direct consumption in local markets. The model was generally the same as scenario 1, except that juice and syrup sulfitation were included, the boiling scheme was modified, and transport of products was included. The additional variable inputs were as shown in Table 3.
Table 3—Additional variable model inputs: field-to-market plantation white sugar.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value/range</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Juice sulfur usage (ppm to cane equivalent)</td>
<td>500 (300–600)</td>
<td>PERT</td>
</tr>
<tr>
<td>Syrup sulfur usage (ppm to cane equivalent)</td>
<td>100 (50–200)</td>
<td>PERT</td>
</tr>
<tr>
<td>Average road distance to market (km): sugar</td>
<td>100 (50–300)</td>
<td>PERT</td>
</tr>
<tr>
<td>Road distance to market (km): molasses</td>
<td>100 (10–500)</td>
<td>PERT</td>
</tr>
<tr>
<td>Road distance to market (km): ethanol</td>
<td>100 (10–500)</td>
<td>PERT</td>
</tr>
<tr>
<td>Road freight fuel efficiency (tonne.km per litre)</td>
<td>21 (18–26)</td>
<td>PERT</td>
</tr>
</tbody>
</table>

Results

The distribution of the results from the 3000 model simulations generally mimicked that of the raw sugar scenario in Figure 2, except that the carbon footprint is around 100–150 g CO₂eq/kg sugar higher. The mean, median, minimum, maximum and 5% and 95% percentiles from the 3000 model simulations are shown in Appendix 2, with the equivalent values for each of scenarios 1 to 5. As before, Appendix 1 shows the breakdown of the carbon footprint by category. This shows that the biggest contributor to the increase is product transport (50%), followed by increased chemical usage (30%) and increased net energy usage (20%).

Scenario 3: Field-to-market refined sugar (refinery annexed to factory)

The third scenario modelled was the production of refined sugar in a refinery annexed to a factory, including product transport (sugar, molasses and ethanol) to market. The model was generally the same as scenario 1 except that all raw sugar produced was processed into refined sugar and transport of products was included (similar to scenario 2). The refinery processes were assumed to include melting; phosphatation clarification; filtration, powdered activated carbon (PAC) or ion exchange (IER) with brine recovery; crystallisation; and drying. The heat energy to the refinery was provided by bleeding factory evaporator vapour where available. The additional variable inputs are shown in Table 4.

Table 4—Additional variable model inputs (refinery annexed to factory).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value/range</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugar colour to refinery (IU)</td>
<td>1000 (800–1200)</td>
<td>PERT</td>
</tr>
<tr>
<td>Decolourisation by PAC or IER</td>
<td>50%/50%</td>
<td>Discrete</td>
</tr>
<tr>
<td>IER colour removal per cycle (BV.IU)</td>
<td>22 500 (20 000–30 000)</td>
<td>PERT</td>
</tr>
<tr>
<td>PAC dose rate (% to sugar throughput)</td>
<td>0.1% (0.05–0.2%)</td>
<td>PERT</td>
</tr>
</tbody>
</table>

Results

Figure 4 shows the distribution of the results from the 3000 model simulations, and Appendix 2 compares the results with the other scenarios 1–5.
Compared to the plantation white scenario, the carbon footprint is around 50 (between 0 and 160) CO\textsubscript{2eq}/kg sugar higher. Appendix 1 shows that the mean increase in carbon footprint is mostly due to an increase in fossil fuel usage, mitigated by a reduction in chemical usage.

**Sensitivity analysis**

Figure 5 shows the sensitivity analysis chart. The top-ranked input is the heat loss factor, i.e. the process energy efficiency of the factory and refinery. This is a logical result: for raw sugar production alone, a factory can often afford to be energy inefficient and still be self-sufficient in steam from bagasse; whereas the addition of an annexed refinery makes it more important to focus on factory energy efficiency.

![Figure 5—Sensitivity analysis: field-to-market refined sugar (refinery annexed to factory).](image)

**Scenario 4: Raw sugar port to refined market (i.e. raw shipping, refining and transport)**

The fourth scenario modelled was raw sugar refining in a destination refinery, including shipping by sea of raw sugar to the refinery, and product transport (refined sugar and molasses) to market.

The starting point for each simulation was 1 million tonnes of raw sugar at a port in the country of origin. Variable inputs are listed in Tables 5 and 6.

**Table 5**—Variable (discrete) model inputs: destination refinery.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value/Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of simulations processing VHP quality sugar (remainder use affination)</td>
<td>50%</td>
</tr>
<tr>
<td>% of simulations with phosphatation (remainder have carbonatation)</td>
<td>60%</td>
</tr>
<tr>
<td>% of simulations with bone char/GAC(^{17})/IER for decolourisation</td>
<td>20%/30%/50%</td>
</tr>
<tr>
<td>% of simulations including export of surplus power to grid</td>
<td>20%</td>
</tr>
<tr>
<td>% of simulations using coal/oil/gas as fuel</td>
<td>30%/10%/60%</td>
</tr>
</tbody>
</table>

**Results**

Figure 6 shows the distribution of the results from the 3000 model simulations, and Appendix 2 compares the results with the other scenarios 1–5. Appendix 1 shows that around 75% of the carbon footprint is due to fossil fuel usage, with the remainder split between product transport, raw sugar shipping and process chemicals.

\(^{17}\) Granular activated carbon.
Table 6—Variable (continuous) model inputs: destination refinery.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value/range</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw (non-VHP) sugar colour to refinery (IU)</td>
<td>3000 (1500–5000)</td>
<td>PERT</td>
</tr>
<tr>
<td>VHP sugar colour to refinery (IU)</td>
<td>1000 (500–1200)</td>
<td>PERT</td>
</tr>
<tr>
<td>Refinery energy efficiency</td>
<td>18</td>
<td>PERT</td>
</tr>
<tr>
<td>Refinery process efficiency</td>
<td>19</td>
<td>PERT</td>
</tr>
<tr>
<td>Power generation turbine overall efficiency</td>
<td>70% (50–80%)</td>
<td>PERT</td>
</tr>
<tr>
<td>Carbonation lime dosing (ppm CaO to DS$^{20}$ in feed)</td>
<td>6000 (4500–9000)</td>
<td>PERT</td>
</tr>
<tr>
<td>Bone char burn rate (kg per kg DS in feed)</td>
<td>10% (5–15%)</td>
<td>PERT</td>
</tr>
<tr>
<td>GAC burn rate (kg per kg DS in feed)$^{21}$</td>
<td>0.8% (0.4–1.4%)</td>
<td>PERT</td>
</tr>
<tr>
<td>IER colour removal per cycle (BV.IU)</td>
<td>22 500 (20 000–30 000)</td>
<td>PERT</td>
</tr>
<tr>
<td>Raw sugar sea shipping distance to refinery (km)</td>
<td>8000 (2000–20000)</td>
<td>PERT</td>
</tr>
<tr>
<td>Average road distance to market (km): refined sugar</td>
<td>100 (50–300)</td>
<td>PERT</td>
</tr>
<tr>
<td>Average road distance to market (km): molasses</td>
<td>100 (10–500)</td>
<td>PERT</td>
</tr>
<tr>
<td>Road freight fuel efficiency (tonne.km per litre)</td>
<td>21 (16–26)</td>
<td>PERT</td>
</tr>
</tbody>
</table>

Fig. 6—Carbon footprint variability: raw sugar port to refined market.

Comparison with other published estimates
Rein (2011) estimated a value of 417 g CO₂eq/kg sugar for refining alone (i.e. excluding transport). Rein also reported values for raw sugar transport to a destination refinery of 48 (Thailand to Japan) and 140 kg CO₂eq/t sugar (Mauritius to Europe), although it is not clear if these include overland transport from factory to port. These values are of the same order as the results shown above and in Appendix 1.

Sensitivity analysis
Figure 7 shows the sensitivity analysis chart. The top-ranked input is the heat loss factor, i.e. the refinery energy efficiency. This is logical as the majority of emissions are due to fossil fuel usage. Other key drivers are transport distances and efficiencies, power generation and process configuration. Of the options included, the configuration with the lowest carbon footprint is VHP sugar refined using phosphatation and either IER or GAC.

$^{18}$ The variability of process energy efficiency is applied in the model via an Energy Efficiency Factor. This factor was set at 1 and allowed to vary between 0 and 5. These values roughly correspond with an exhaust steam usage of 1.09 t/t sugar (varying between 0.9 and 1.45).

$^{19}$ The variability of process efficiency is applied in the model via a Sugar Loss Factor. This factor was set at 1 and allowed to vary between 0.5 and 4. These values roughly correspond with an overall sucrose yield of 98% (varying between 99% and 96%).

$^{20}$ Dry solids

$^{21}$ kg of GAC sent to kiln for regeneration per kg of sugar (dry solids) processed
Fig. 7—Sensitivity analysis: raw sugar port to refined market.

Scenario 5: Field-to-market refined sugar (refinery separate from factory)

The fifth scenario modelled included raw sugar production (as scenario 1), transport to a refinery, refining and product transport (as scenario 4). The refinery could be either within the country of origin or in the country of destination. The starting point for each simulation, as in scenario 1, was 20,000 ha of sugarcane production. The additional or modified variable inputs are:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value/range</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refinery located with road distance of factory</td>
<td>15%</td>
<td>Discrete</td>
</tr>
<tr>
<td>Road distance from factory to refinery (km)</td>
<td>50 (0–200)</td>
<td>PERT</td>
</tr>
<tr>
<td>Road distance from factory to port (km)</td>
<td>400 (10–1000)</td>
<td>PERT</td>
</tr>
</tbody>
</table>

Results

Figure 8 shows the distribution of the results from the 3000 model simulations, and Appendix 2 compares the results with the other scenarios 1–5. Appendix 1 shows that around half of the emissions are due to agriculture, with around 40% from processing (mainly fossil fuel usage in refining) and the remainder in transport. Road transport contributes around double the emissions of sea transport.

Fig. 8—Carbon footprint variability: field-to-market refined (refinery separate from factory).
Comparison with other published estimates

The literature survey in Klenk et al. (2012) included two estimates for raw sugar shipped and refined in another country: 630 and 534 g CO$_{2eq}$/kg sugar. Rein (2012) reported an estimate of 570 g CO$_{2eq}$/kg sugar in the US. Tate & Lyle (2009) reported a carbon footprint of 380 g CO$_{2eq}$/kg retail sugar (field-to-use), while Florida Crystals (2008) reported carbon-neutral refined sugar (i.e. carbon footprint of zero). These values are all at the lower end of the distribution in Figure 8.

Sensitivity analysis

Figure 9 shows the sensitivity analysis chart. The highest-ranked input is the road distance from factory to port (as this was defined in Table 7, it is highly variable). The other inputs are dominated by agriculture, power production and energy efficiency.

![Fig. 9—Sensitivity analysis: field-to-market refined sugar (refinery separate from factory).](image)

Scenario 6: Low emissions refined sugar

Scenario 6 was a single static simulation in which the key drivers as identified above were manipulated to achieve low-emissions refined sugar. The inputs manipulated are listed in Table 8. The other inputs remained at their ‘most likely’ values (i.e. without ranges) as in scenario 3.

**Table 8—Inputs manipulated: low-emissions refined sugar.**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Country of origin</td>
<td>India$^{21}$</td>
</tr>
<tr>
<td>Cane yield (t/ha)</td>
<td>70.1$^{22}$</td>
</tr>
<tr>
<td>Irrigation water usage (mm/year)</td>
<td>500</td>
</tr>
<tr>
<td>Electric irrigation pumps</td>
<td>100%</td>
</tr>
<tr>
<td>Amount of nitrogen required as fertiliser (kg/ha)</td>
<td>75</td>
</tr>
<tr>
<td>Amount of lime required on fields (kg/ha)</td>
<td>500</td>
</tr>
<tr>
<td>Filter mud returned to fields?</td>
<td>Yes</td>
</tr>
<tr>
<td>Distillery attached?</td>
<td>No</td>
</tr>
<tr>
<td>Refinery annexed to factory (i.e. not separate)?</td>
<td>Yes</td>
</tr>
<tr>
<td>Process steam-on-cane (approx.)</td>
<td>40%</td>
</tr>
<tr>
<td>% of cane burnt</td>
<td>0%</td>
</tr>
<tr>
<td>Surplus power exported to grid?</td>
<td>Yes</td>
</tr>
<tr>
<td>Boiler pressure (bar)</td>
<td>100</td>
</tr>
<tr>
<td>Power generation turbine overall efficiency</td>
<td>80%</td>
</tr>
<tr>
<td>Mill drives electrified</td>
<td>100%</td>
</tr>
</tbody>
</table>

$^{21}$ India is selected because it has a high emissions factor for average electricity production (264 g CO$_{2}$/MJ, compared to 21 g CO$_{2}$/MJ for Brazil, for example), therefore increasing the credit for power exports (see footnote 2).

$^{22}$ Average for India.
The results are shown in Appendix 1. The total carbon footprint is –262 g CO$_2$eq/kg sugar. The negative carbon footprint is due to the large credit allocated to power export (–700 g CO$_2$eq/kg sugar). Agricultural nitrogen and irrigation are the biggest contributors to emissions.

**Scenario 7: Very low emissions refined sugar**

Scenario 7 was the same as scenario 6, except that 100% of the land was mechanically harvested and 50% of cane trash was recovered and burnt in the boiler (constituting 20% of the total boiler fuel). The results are shown in Appendix 1. The total carbon footprint is –565 g CO$_2$eq/kg sugar. The power export credit is now over 1000 g CO$_2$eq/kg sugar (the actual power export is around 1.1 MWh/tonne sugar).

**Scenario 8: Extremely low emissions refined sugar**

Scenario 8 was the same as scenario 7, except that bagasse and trash were processed via biomass gasification with power produced via gas turbines. The results are shown in Appendix 1. The total carbon footprint is –1469 g CO$_2$eq/kg sugar. The power export credit is now almost 2700 g CO$_2$eq/kg sugar (the actual power export is around 2.8 MWh/tonne sugar). The emissions due to chemical manufacture and transport increase by almost 700 g CO$_2$eq/kg due to gasifier chemical usage.

**Summary of results**

The results from the various scenarios are summarised. These results and conclusions are based on the assumptions listed in the paper. The nature of variable modelling carried two benefits in this regard: (a) by expressing inputs and outputs as ranges, the results are not so reliant on the accuracy of data for any single input; and (b) the sensitivity analysis highlights which assumptions are most crucial to the final results.

1. The carbon footprint of raw sugar worldwide varied in 90% of simulations between 217 and 809 g CO$_2$eq/kg sugar, with a mean of 441 g CO$_2$eq/kg.
2. The biggest drivers of variability in raw sugar carbon footprint were the country of origin, agricultural methods, power production/export and process energy efficiency.
3. Production of plantation white sugar and transport to a local market added around 100–150 g CO$_2$eq/kg to the carbon footprint, due to product transport (50%), increased chemical usage (30%), and increased energy usage (20%).
4. The global carbon footprint of refined sugar (refinery annexed to factory) varied in 90% of simulations between 329 and 1121 g CO$_2$eq/kg sugar, with a mean of 598 g CO$_2$eq/kg. The increase from raw sugar was mostly due to fossil fuel usage, and the biggest driver of variability was process energy efficiency.
5. The carbon footprint associated with shipping raw sugar from port, refining at a destination refinery, and transporting to market varied in 90% of simulations between 465 and 660 g CO$_2$eq/kg sugar, with a mean of 558 g CO$_2$eq/kg. The biggest driver of variability was process energy efficiency.
6. The global carbon footprint of refined sugar (refinery separate to factory) varied in 90% of simulations between 621 and 1459 g CO$_2$eq/kg sugar, with a mean of 1022 g CO$_2$eq/kg. The key drivers were similar to the previous case, with the addition of the distance from factory to port.
7. By manipulating the key drivers, a refined sugar carbon footprint of –260 g CO$_2$eq/kg sugar can be achieved. This increases to –565 g CO$_2$eq/kg if trash recovery is carried out and –1470 g CO$_2$eq/kg if biomass gasification is adopted.

**Conclusions**

The potential variation in the carbon footprint of raw and refined cane sugar is large, depending on where and how it is produced. This poses a problem, particularly for refined sugar manufacturers and consumers, in that stating a specific product emissions level is difficult if not
impossible. It also presents an opportunity, particularly in raw sugar manufacture and annexed refineries, in that the key drivers can be manipulated to achieve a low-emissions product. Plantation white and factory-refined sugar have a significant advantage over destination-refined white sugar.

By focussing on the areas of irrigation, nitrogen and lime application, cane yields, power generation and export, process energy efficiency and cane burning, refined cane sugar can realistically achieve a negative carbon footprint, i.e. a net emissions credit of 260 g CO$_2$eq/kg sugar. This could increase to 565 g CO$_2$eq/kg if trash recovery is implemented, and to 1470 g CO$_2$eq/kg with biomass gasification. Florida Crystals have already shown in 2009 that a carbon neutral refined sugar can be produced (due to emissions credits from power generation and export).

The carbon footprint values stated in this paper are based on the Bonsucro method of analysis with assumptions, modifications and additions as stated in the paper. One critical assumption is that no non-agricultural land was converted to agricultural use after 1 January 2008. This effectively eliminates any impacts from direct or indirect land use change. It is important to understand the methodology and its boundaries when comparing these results with other published estimates.

REFERENCES


Tate & Lyle. (2009). Tate & Lyle Reduces Its Footprint With The Carbon Trust. [http://tinyurl.com/a5kovfz](http://tinyurl.com/a5kovfz)
Appendix 1—Results from all scenarios (mean values from 3000 simulations).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>585 612 619 0 594 260 279 279</td>
<td>805 875 875 0 870 312 321 321</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transportation of cane</td>
<td>45 47 49 0 46 34 45 45</td>
<td>67 71 71 0 67 34 45 45</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feedstocks (e.g., raw sugar)</td>
<td>0 0 0 0 0 0 0 0</td>
<td>0 0 0 0 0 0 0 0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Processing (excluding electricity)</td>
<td>121 192 211 459 551 72 76 72</td>
<td>121 192 211 459 551 72 76 72</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local transport of products</td>
<td>0 0 0 0 0 0 0 0</td>
<td>0 0 0 0 0 0 0 0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total (ex sea transport)</td>
<td>690 873 910 507 1,239 -262 -612 -2,590</td>
<td>690 873 910 507 1,239 -262 -612 -2,590</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Allocation to bagasse</td>
<td>0 0 0 0 0 0 0 0</td>
<td>0 0 0 0 0 0 0 0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Allocation to molasses</td>
<td>33 43 34 2 42 -42 -47 -121</td>
<td>33 43 34 2 42 -42 -47 -121</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Allocation to ethanol</td>
<td>216 260 267 0 216 0 0 0</td>
<td>216 260 267 0 216 0 0 0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>441 550 598 559 1,025 -262 -565 -1,469</td>
<td>441 550 598 559 1,025 -262 -565 -1,469</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**DETAIL**

- **Agricultural chems manufacture & application**
  - Nitrogen: 88 86 89 0 93 14 14 14
  - K2O: 15 15 16 0 14 6 6 6
  - P2O5: 9 9 9 0 10 9 9 9
  - CaCO3: 68 70 72 0 65 19 19 19
  - Herbicide: 11 11 11 0 11 0 0 0
  - Insecticide: 1 1 1 0 1 1 1 1
  - Total: 191 191 198 0 193 49 56 56

- **N2O from cane/trash/filter mud/whatis**
  - Cane stalk residue: 6 6 5 0 6 5 5 5
  - Cane trash residue: 32 33 34 0 30 45 23 23
  - Filter cake: 63 67 67 0 62 56 56 56
  - Vinasse: 29 32 32 0 26 0 0 0
  - Total: 131 138 138 0 125 107 84 84

- **Agricultural fuel & energy**
  - Diesel fuel for transport: 32 33 33 0 32 21 46 46
  - Diesel fuel for irrigation: 123 139 138 0 130 0 0 0
  - Electricity used in irrigation: 31 30 29 0 33 90 90 90
  - Total: 185 202 201 0 195 110 136 136

- **Cane burnt**
  - CH4 produced in cane burning: 59 61 62 0 60 0 0 0
  - N2O produced in cane burning: 19 20 20 0 20 0 0 0
  - Total: 78 81 83 0 80 0 0 0

- **Cane transport**
  - Diesel fuel for cane transport: 45 47 48 0 46 34 45 45
  - Total: 45 47 48 0 46 34 45 45

- **Bagasse burnt**
  - CH4 produced in bagasse burning: 25 26 26 0 24 10 10 10
  - N2O produced in bagasse burning: 1 1 1 0 1 1 1 1
  - Total: 26 26 27 0 25 19 19 19

- **Fossil fuels**
  - Fossil fuels burnt in boiler: 9 35 75 411 421 0 0 0
  - Gas burnt in kilns: 0 0 0 0 0 0 0 0
  - Electricity imported/exported: -61 -55 -55 -70 -75 -1,069 -2,656 -2,656
  - Total: -51 -20 17 410 351 -283 -612 -2,590

- **Process chemicals**
  - Lime (CaO): 1 3 2 0 1 1 1 1
  - Caulif: 68 71 74 14 90 33 36 36
  - Sulphuric acid: 2 2 2 0 2 0 0 0
  - Miscellaneous: 11 50 27 25 25 17 17 17
  - Total: 82 128 193 40 118 50 54 731

- **Wastewater**
  - Treatment: 3 3 3 0 3 3 3 3
  - Raw water intake: 2 2 2 0 3 1 1 1
  - Total: 5 5 5 3 6 3 3 3

- **Road transport of products**
  - Diesel fuel for granulated sugar transport: 0 0 0 0 0 0 0 0
  - Diesel fuel for liquid sugar transport: 0 0 0 0 0 0 0 0
  - Diesel fuel for molasses transport: 0 0 0 0 0 0 0 0
  - Diesel fuel for ethanol transport: 0 0 0 0 0 0 0 0
  - Total: 0 0 0 0 0 0 0 0

- **Sea transport of products**
  - Raw sugar from factory to refinery: 0 0 0 0 0 0 0 0
  - Total: 0 0 0 0 0 0 0 0
Appendix 2—Results comparison (Scenarios 1–5).

<table>
<thead>
<tr>
<th>No</th>
<th>Scenario</th>
<th>Min</th>
<th>5%</th>
<th>Median</th>
<th>Mean</th>
<th>95%</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Field-to-factory-gate raw sugar</td>
<td>121</td>
<td>217</td>
<td>390</td>
<td>441</td>
<td>80</td>
<td>2251</td>
</tr>
<tr>
<td>2</td>
<td>Field-to-market plantation white sugar</td>
<td>35</td>
<td>327</td>
<td>490</td>
<td>550</td>
<td>96</td>
<td>2161</td>
</tr>
<tr>
<td>3</td>
<td>Field-to-market refined sugar (refinery annexed to factory)</td>
<td>126</td>
<td>329</td>
<td>529</td>
<td>598</td>
<td>11</td>
<td>2114</td>
</tr>
<tr>
<td>4</td>
<td>Raw sugar port to refined market (i.e. raw shipping, refining &amp; transport to market)</td>
<td>395</td>
<td>465</td>
<td>555</td>
<td>558</td>
<td>66</td>
<td>1227</td>
</tr>
<tr>
<td>5</td>
<td>Field-to-market refined sugar (refinery separate from factory)</td>
<td>114</td>
<td>621</td>
<td>995</td>
<td>1022</td>
<td>14</td>
<td>2885</td>
</tr>
</tbody>
</table>

All values are g CO₂ per kg sugar

LA VARIABILITE ET LES FACTEURS DETERMINANTS DE L'EMPREINTE CARBONE DE LA CANNE A SUCRE

Par

J. FISHER

Process Technology Tate & Lyle

jack.fisher @ asr-group.com

MOTS-CLÉS: Empreinte Carbone, Simulation de Monte Carlo.

Résumé

L'EMPREINTE CARBONE (émissions de GES) de la canne à sucre est de plus en plus d'intérêt pour les utilisateurs et les consommateurs de sucre. Cette étude considère la variabilité potentielle à l'échelle mondiale de l'empreinte carbone de la canne à sucre, et examine les principaux facteurs qui influencent cette variabilité. Un modèle mathématique a été conçu pour représenter la production de sucre du champ au marché. Les données d'entrée clés ont été remplacées par des fourchettes pour refléter la variabilité et l'incertitude associées à la diversité des scénarios de production de sucre à travers le monde. La simulation de Monte Carlo a été réalisée pour simuler l'effet de ces variations sur les résultats modèles, qui ont été évalués en fonction de la méthode Bonsucro (avec des modifications et des ajouts) pour estimer les émissions de GES. L'empreinte carbone du sucre roux, du champ à la porte, se situait entre 217 et 809 g de CO₂eq par kilo de sucre dans 90% des simulations. Les facteurs les plus importants ont été le pays d'origine, les pratiques agricoles, la production/exportation d'énergie et l'efficacité énergétique de la fabrication. La production de sucre blanc et le transport vers un marché local ont ajouté 100–150 g additionnels de CO₂eq/kg, répartis entre les émissions du transport et de la fabrication. L'empreinte carbone du sucre raffiné, du champ au marché, se situait entre 329 et 1121 g CO₂eq/kg. L'augmentation par rapport au sucre roux est principalement due à l'utilisation accrue de combustible fossile, et le plus important facteur était l’efficacité énergétique de la fabrication. L'empreinte carbone associée à l'expédition du sucre roux à partir du port, le raffinage effectué dans une raffinerie à destination, et le transport au marché, a varié entre 465 et 660 g CO₂eq/kg. Le plus important facteur était l’efficacité énergétique de la raffinerie. Enfin, l'empreinte carbone du sucre raffiné, du champ au marché de destination, a varié
entre 621 et 1459 g CO$_{2eq}$/kg dans 90% des simulations, la distance entre l'usine et le port étant un facteur supplémentaire significatif. Il a été démontré que la variabilité potentielle de l'empreinte carbone de la canne à sucre est grande, selon le lieu et la façon dont elle est produite. Cependant, en se concentrant sur des domaines tels l'irrigation, les produits agrochimiques, les rendements de canne, la production et l'exportation d'électricité, l'efficience énergétique de la fabrication et le brûlage de la canne, il est réaliste d'atteindre un bilan carbone négatif pour le sucre raffiné, champ au marché: un crédit net des émissions de 260 g CO$_{2eq}$/kg a été simulé, en améliorant à 565 g CO$_{2eq}$/kg avec récupération des déchets et à 1470 g CO$_{2eq}$/kg avec gazéification de la biomasse.

LA VARIABILIDAD Y LOS CONTROLADORES DE LA HUELLA DE CARBONO DEL AZÚCAR DE CAÑA

Por

J. FISHER
Tate & Lyle Process Technology
jack.fisher@asr-group.com

PALABRAS CLAVE: Huella de Carbon,
Simulación Monte Carlo.

Resumen

LA HUELLA DE CARBONO (emisiones de GEI’s) del azúcar es un tema de creciente interés para los consumidores y usuarios del azúcar. Este estudio considera la variabilidad potencial global de la huella de carbono de la caña de azúcar e investiga los factores clave que afectan dicha variabilidad. Se construyó un modelo matemático que representa la producción de azúcar desde el campo hasta el mercado. Se reemplazaron los valores clave de ingreso por rangos para reflejar la variabilidad y la incertidumbre asociadas con los distintos escenarios de producción mundial del azúcar. Se utilizó una simulación Monte Carlo para emular el efecto de estas variaciones en las salidas del modelo, las cuales fueron evaluadas contra el método Bonsucro para estimar las emisiones de GEI’s (con modificaciones y adiciones). La huella de carbono del azúcar crudo desde el campo a la puerta del ingenio estuvo entre 217 y 809 g de CO$_{2eq}$/kg por kilogramo de azúcar en el 90% de las simulaciones. Los factores de mayor impacto fueron el país de origen, métodos agrícolas, producción/exportación de energía y la eficiencia energética del proceso. La producción y el transporte de azúcar blanca estándar al mercado local añadieron otros 100–150 g CO$_{2eq}$/kg, repartidos entre emisiones causadas por el transporte y por el procesamiento. La huella de carbono del azúcar refinado del campo-ingenio-mercado estuvo entre 329 y 1121 g CO$_{2eq}$/kg. El incremento, comparado con el azúcar crudo, se debe al mayor uso de combustibles fósiles y el principal factor clave fue la eficiencia energética del proceso. La huella de carbono asociada con el embarque del azúcar crudo del puerto, el proceso de refinamiento en una refinería de destino y el transporte a mercado final estuvo entre 465 y 660 g CO$_{2eq}$/kg. El factor de mayor impacto fue la eficiencia energética de la refinería. Finalmente, la huella de carbono del azúcar refinado campo-mercado de destino varió entre 621 y 1459 g CO$_{2eq}$/kg en el 90% de las simulaciones, de lo cual la distancia del ingenio al puerto fue un factor clave significativo adicional. Se ha demostrado que la variabilidad potencial de la huella de carbono de la caña de azúcar es grande, dependiendo de dónde y cómo se produce. Sin embargo, al enfocarse en áreas como riego, uso de productos químicos agrícolas, productividad del cultivo, generación y exportación de energía, eficiencia energética del proceso y quema de caña, es posible obtener una huella de carbono negativa para el azúcar refinado del campo al mercado: se simuló un crédito por emisiones netas de 260 g CO$_{2eq}$/kg, mejorando a 565 g CO$_{2eq}$/kg después de la recuperación de los residuos (trash) y hasta 1470 g CO$_{2eq}$/kg después de la gasificación de la biomasa.
A VARIABILIDADE E OS CONDUTORES DAS PEGADAS DE CARBONO DA CANA-DE-AÇÚCAR

Por

J. FISHER

Tate & Lyle Process Technology

jack.fisher@asr-group.com

PALAVRAS-CHAVE: Pegada de Carbono, Simulação Monte Carlo.

Resumo

A PEGADA DE CARBONO (emissões GHG) do açúcar tem atraído interesse de usuários e consumidores. Este estudo avalia a variabilidade potencial em nível mundial da pegada de carbono da cana-de-açúcar e investiga os principais condutores que afetam essa variabilidade. Um modelo matemático foi construído para representar a produção de açúcar do campo ao mercado. Valores de entrada principais foram substituídos por variações para refletir a variabilidade e a incerteza associadas à diversidade dos cenários de produção de açúcar em todo o mundo. A simulação Monte Carlo foi realizada para simular o efeito dessas variações nas saídas dos modelos, que foram avaliadas à luz do método Bonsucro (com modificações e adições) para estimar as emissões GHG. A pegada de carbono do campo até a porteira de açúcar bruto variou entre 217 e 809 g CO₂eq por kg de açúcar em 90% das simulações. Os principais condutores foram o país de origem, os métodos de cultivo, a produção/exportação de energia e a eficiência energética do processo. A produção de uma cultura de açúcar branco e transporte a um mercado local adicionou 100–150 g CO₂eq/kg, divididos entre as emissões de transporte e processamento. A pegada de carbono do campo até o mercado para o açúcar refinado variou entre 329 e 1121 g CO₂eq/kg. O aumento do açúcar bruto foi devido basicamente a um maior uso de combustível fóssil e o maior condutor do processo foi a eficiência energética. A pegada de carbono associada ao embarque do açúcar bruto do porto, com refino na refinaria de destino e transporte ao mercado variou entre 465 e 660 g CO₂eq/kg. O maior condutor foi a eficiência energética da refinaria. Finalmente, a pegada de carbono do campo para o mercado do açúcar refinado variou entre 621 e 1459 g CO₂eq/kg em 90% das simulações, das quais a distância da fábrica ao porto foi um condutor adicional significativo. A variabilidade potencial na pegada de carbono da cana tem se mostrado bastante grande, dependendo de onde e como ela é produzida. Por outro lado, ao focarmos em áreas como irrigação, químicos agrícolas, produtividade da cana, geração e exportação de energia, eficiência energética do processo e queima de cana, é possível alcançar uma pegada de carbono negativa para o percurso do açúcar refinado do campo até o mercado: um crédito líquido de emissões de 260 g CO₂eq/kg foi simulado, melhorando para 565 g CO₂eq/kg com a recuperação da palha e 1470 g CO₂eq/kg com a gasificação da biomassa.
EFFECTIVE RESEARCH ANALYSIS AND TECHNOLOGY TRANSFER USING A MULTIDISCIPLINARY APPROACH: A SUMMARY OF THE 3RD ISSCT MANAGEMENT AND TECHNOLOGY TRANSFER WORKSHOP

By

F.C. BOTHA\textsuperscript{1} and M.C. GOPINATHAN\textsuperscript{2}

\textsuperscript{1}BSES Limited, Indooroopilly, Australia
\textsuperscript{2}EID Parry (India) Limited, Bangalore, India
\email{fbotha@bses.com.au}

KEYWORDS: R&D Landscape, Innovative Management, Extension Models, Small Scale Farmers, Production Plateaus.

Abstract

This paper summarises the activities of the ISSCT Management and Technology Transfer workshop held 24–27 August 2011 in Mamallapuram, Tamil Nadu, India. Presentations were grouped in four sessions: delivery of extension to small-scale growers; packing and delivery of technology; managing innovation and diversification; managing technology development and extension. Included in the workshop was a 2-day tour to the Nellikuppam region (100 km south of Mamallapuram), one of the oldest sugarcane growing and processing areas in India. Highlighted was the evolution and growth of a modern integrated complex biofactory that produces sugar, ethanol, biogas, bio-earth and cogeneration of electricity from sugarcane biomass, while the second day focused on small-scale farmers. The workshop concluded that recent increased involvement of major agribusinesses will further enhance the pace of change, that RD&E needs to develop a stimulating environment for innovative research, that extension models be revisited to meet customer needs, that information from other industries and multinationals be integrated in the management and research program; that there is an urgent need for a pool of young talent in sugarcane R,D&E, and that effective linkages between miller and farmer and their full participation and support are essential for the successful delivery of research results faster and better to ensure profitability and sustainability of all stakeholders.

Introduction

The 3\textsuperscript{rd} ISSCT Management Workshop was held from 24 to 27 August 2011 in Temple Bay, Mamallapuram, Tamil Nadu, India. The workshop was attended by 42 delegates from seven countries (Australia, Fiji, Mauritius, Thailand, Japan, Iran and India) (Figure 1).

The theme of the workshop was Effective Research Analysis and Technology Transfer Using a Multidisciplinary Approach and consisted of a pre-workshop tour and a technical session.

The four topics in the technical sessions were:
- Delivery of extension to small-scale growers,
- Packing and delivery of technology,
- Managing innovation and diversification,
- Managing technology development and extension.

Location of the workshop was the historic 7\textsuperscript{th} century port city of southern India famous for its shore temples and ancient architecture and has been classified as a UNESCO World Heritage site. The workshop was hosted by EID Parry India Ltd, a company established in 1788 and
presently engaged in the manufacture and marketing of a wide range of products such as sugar, alcohol, co-generation of power, nutraceuticals and bioproducts.

Fig. 1—Delegates attending the 3rd ISSCT Management Workshop held from 24 to 27 August 2011 in Temple Bay, Mamallapuram, Tamil Nadu, India.

Pre-workshop tour

The ISSCT Management Workshop started with a two-day pre-workshop factory and field tour (24–25 August) of the Nellikuppam region of Tamil Nadu (100 km south of Mamallapuram). This is one of the oldest sugarcane growing and processing areas in India, dating back to 1842. In his presentation, the General Manager of the EID Parry-owned factory, Mr Bharni Kumar, provided an overview of activities that resulted in the evolution and growth of one of the oldest sugarcane processing plants to a modern integrated complex bio-factory that produces sugar, ethanol, biogas, bio-earth and cogeneration of electricity from sugarcane biomass. This overview was followed by site visits to the sugarcane milling plant, distillery, cogeneration power plant, refinery and the biogas and bio-earth facilities. An extensive buffet lunch was provided in the mill’s dining room (Figure 2).

Fig. 2—Factory visits and general manager’s presentation.
Day one concluded with a visit to Chidambaram, a 2nd century BC temple which has been attracting pilgrims for over two millennia. Delegates overnighted in Pondicherry.

The second day focused on small-scale farmers. Visits included Parry’s Edyenvelli Cane Research Farm (variety, entomological and agronomic trials), an advisory-agronomic supply service centre and a privately operated *Trichogramma* production centre (biological pest control).

The field visit provided ample opportunity for the participants to interact with small-scale sugarcane farmers to understand their livelihood, sugarcane productivity improvement issues and their technology expectations.

The visit also included inspection of the advanced breeding trial plots and commercial variety evaluation trials and demonstration of various agro technologies on the Parry research farms and small-scale farmers’ fields. Participants were also updated on the technology transfer and extension work carried out by EID Parry to small-scale farmers (Figure 3).

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**Fig. 3—Participants attend technology demonstration plots and presentations.**

### Opening session

The technical session of the workshop commenced with the traditional invocation (Figure 4) seeking the Almighty’s blessing and the Lighting of a Lamp that signifies the willingness to remove ignorance and acquire knowledge. Dr Gopinathan, the Workshop Coordinator, welcomed the delegates.

In his inaugural presentation, Ravindra S. Singhvi, the Managing Director of E.I.D. Parry (I) Ltd, provided an overview of the agricultural and economic characteristics of the Indian sugar industry and how EID Parry approach technology transfer to farmers to improve their productivity and profitability (Figure 5). He emphasised that the sustainability of sugar businesses depends on locking in farmers through service and partnership.

Parry’s challenge is bringing every farmer within the potential limits of productivity and best in profitability irrespective of the size of the farming enterprise, economic status, education, age and culture. This can only be achieved if farmers are viewed and treated as critical customers.

Dr Frikkie Botha, Commissioner and Chair of the Management and Technology Transfer Section (Australia), in his keynote address focused on the changing sugarcane R,D&E landscape and emphasised the urgent need for delivery to meet stakeholder expectations.

World-wide, many production areas are faced with a yield plateau, and in some cases even yield declines. For many areas, this has been evident for more than three decades. To break out of this yield plateau, new and innovative approaches are required. It should be evident that more of the same is just simply no longer good enough.

This means RD&E management requires true leadership, forward-thinking, vision, integration of stakeholders, new partnerships, investment in new approaches, and coordination of research to generate a better and secure future.
As with tradition of Parry hospitality, a cultural event was organised for participants on the evening of the first day of the workshop, with a hearty cocktail and dinner and the opportunity to enjoy watching, and later participating in, traditional Indian classical dances.

**Session 1: Delivery of extension to small-scale growers**

This session was chaired by David Calcino.

In his paper ‘Revisiting the Practice of Extension to Meet the Needs of the Small-Scale Sugarcane Farmers in Mauritius’ K. Payandi Pillay stressed the importance of a continued evaluation of extension models to ensure alignment with client needs and expectations. The objectives of the extension service to small-scale growers in Mauritius are the reduction in production costs and improving sugarcane yield per unit area.

A survey indicated that 46% of growers did not consult anybody for assistance in their cane and husbandry decisions and only a very small portion of farmers received regular extension visits. In light of these recent findings, there is now a realisation that, rather than purely technology transfer, the extension provision should be focused on enabling the farmers to make better decisions.

In his paper ‘Management of Sugarcane Crop for Upliftment of Farmers’ Dr Krishnamurthy highlighted that the production system for sugarcane is rapidly changing due to mechanisation, marginal environmental conditions and dependence on chemicals.

R,D&E institutions need to recognise these important drivers and revamp their programs to ensure that small-scale growers remain sustainable. Examples referred to included broadening of the germplasm base, biocontrol of pests and diseases, soil amelioration and effective extension.

Dr P. Soman argued that available water and land are two of the most challenging issues facing small-scale growers. In his presentation ‘Drip-fertigation Technology for Sugarcane Agriculture – Field Level Adoption Issues’ he suggested that drip irrigation and fertigation are technologies that could contribute significantly to better sugarcane production by small-scale growers. However, in his view, this would only be possible with much more public and private participation in sugarcane R,D&E.

The power of an integrated approach to technology transfer was illustrated in the presentation ‘Sweet Results of Geo-spatial Technology Applications in Mitr Phol Sugar – Thailand’ by Dr R. Saravanan. At Mitr Phol, a sugarcane information and management system (SIMS) was developed.

This system is based on remote sensing, a geographic information system (GIS) and global positioning system (GPS). The system is a value planning tool for the linking of field and farmers’ information, research technology results and external technology for a one-stop decision-support system.
Session 2: Packing and delivery of technology

The second session was chaired by K Payandi Pillay. The first three papers were from Australia and were presented by David Calcino. In a project led by A.J. Benson, it was demonstrated how a series of integrated weed-management workshops facilitated the adoption of on-farm best management practice.

This grower-friendly, outcome-focused program utilised multidisciplinary teams and was specifically designed for training cane growers. A key for success is the continual review and updating of the package based on feedback from growers, researchers and industry.

A project led by Drewe Burgess demonstrated how sustainable benefits can be achieved by the implementation of an extension program that incorporates existing research, on-going research, on-farm trials, direct grower involvement and extension/technology transfer, and adoption by the farmers.

David Calcino in his paper on ‘Effective Technology Transfer Using a Multidisciplinary Approach: the Development and Extension of Six Easy Steps Workshops in Australia’ shared the success of designing an integrated delivery package workshop for growers incorporating best practice with input from scientists, extension officers and growers. This approach built ownership and enthusiasm and is an example of a successful collaborative extension program in Australia.

In his paper on ‘Innovative Approach on Prescribed Farming in Sugarcane’ A. Jeybal explained how the integration of multiple technologies in a single farm and its demonstration at a farmer’s field could lead to cumulative benefits in productivity.

Session 3: Managing innovation and diversification

Ramesh Ponnuswami chaired this third technical session. In the first paper of this session ‘Sugarcane R, D & E Innovation: Manage It, Measure It… but don't Destroy It’ Frikkie Botha addressed vital issues facing RD&E in sugarcane in comparison to other crops. Research is a high risk endeavour; only 5% of research is successful.

This results in stakeholders and industry leaders often preferentially favouring D and E over R because of its higher predictability and lower failure rate. Three components of R,D&E require entirely different management and execution strategies (needs assessment, priority setting, project scoping, monitoring, evaluation of completed project, evaluation of research outputs, program and management review and impact assessment).

The traditional industry-owned or industry-funded sugarcane R&D entities can gain much by learning from other commodities and successful multinational R&D companies.

The second paper in this session by Y. Tarumoto looked at the evaluation of a new technology for a sugar mill company by using a systems approach. The use of simulation models that incorporated multiple parameters from cane farm to mill in Japan, including regional effects, resulted in better decision making and enabled the industry to increase their productivity on farm and in the mill.

Session 4: Managing technology development and extension

The fourth technical session was chaired by Shivajirao Deshmukh. The first two papers looked at the management of R&D in Iran.

A Rezaei described the history of sugarcane cultivation in Iran and explained efforts of the Past 20 years in research and development to stabilise sugar production through an integrated approach in partnership with the sugar industry.

Dr Hamdi shared experience over the past 12 years in the Iran research and extension programs, especially international collaboration, in breeding, soil, water, agronomy and biological pest management.

M Prabhu emphasised the critical role and need for R&D in sugarcane in Karnataka emphasising low productivity under the diverse agro-climatic conditions in this region.
Dr S.V. Patil described the history of Vasantdada Research Institute and how in partnership with farmers, the industry and academic community success in the research and extension programs resulted in productivity improvements in Maharashtra. He also emphasised the need for further investment in R&D to meet the current and future demands of industry.

U. Pliansinchai shared her experience of customer-driven research for effective implementation of technology in the Mitr Phol Sugar group. Mitr Phol research and extension teams work closely with customers to understand the problems and involve them to make custom tailored solutions with a participatory business approach.

**Panel discussion**

The technical sessions concluded with a panel discussion on the following topics:

- Identification of research priorities
- How to create a research environment that ensures adequate management while stimulating innovation
- How the future R&D landscape will look taking into account all the new big multinational players
- How can extension be optimised and who is best placed to provide such a service?

The discussion was chaired by Frikkie Botha and the panellists were Jai Gawander (Fiji), David Calcino (Australia), Yusuke Tarumoto (Japan), Payandi Pillai (Mauritius), Pipat Weerathaworn (Thailand) and Shivajirao Deshmukh (India).

The main points arising were:

- The sugarcane industry landscape is changing continuously and the recent increased involvement of major agribusinesses will further enhance the pace of change.
- Stakeholder needs are diverse and complex. RD&E needs to develop a stimulating environment for innovative research.
- Extension models to be revisited to meet customer needs.
- Learnings from other industries and multinationals to be integrated in the management and research program.
- There is an urgent need for attract, train and retain a pool of young talent in sugarcane R,D&E.
- Effective linkages between miller and farmer and their full participation and support are essential for the successful delivery of research results faster and better to ensure profitability and sustainability of all stakeholders

**Annual meeting**

The workshop was concluded with a short meeting. The format and quality of the workshop was discussed. The participants agreed on the following:

1. The linkage between the management and extension groups does not work well in the mid-term workshop.
2. Too few senior managers attended the workshop. The participants agreed that it would be much better for the management workshop to be held at the main congress when many of the senior R&D managers are present.
ANALYSE DE LA RECHERCHE EFFICACE ET DU TRANSFERT DE TECHNOLOGIE EN UTILISANT UNE APPROCHE MULTIDISCIPLINAIRE:
RÉSUMÉ DU 3ÈME ATELIER DE TRAVAIL DE L’ISSCT SUR LA GESTION ET LE TRANSFERT DE TECHNOLOGIE

Par

F.C. BOTHÀ1 et M.C. GOPINATHAN2
1BSES Limited, Indooroopilly, Australie
2EID Parry (India) Limited, Bangalore, Inde

MOTS-CLÉS: R&D Paysage, Gestion Innovatrice, Extension des Modèles, Petits Agriculteurs, Plateaux de production.

Résumé
CETTE COMMUNICATION RÉSUME les activités de l’atelier de travail de l’ISSCT sur la Gestion et le Transfert de Technologie qui s’est tenu du 24 au 27 août 2011 à Mamallapuram, Tamil Nadu, en Inde. Les présentations ont été regroupées en quatre sessions: la prestation de la vulgarisation aux petits producteurs; la préparation et le transfert de technologie; la gestion de l’innovation et de la diversification; la gestion du développement des technologies et de la vulgarisation. Une visite de deux jours dans la région de Nellikuppam (100 km au sud de Mamallapuram), une des plus anciennes zones de production sucrière en Inde était incluse dans cet atelier de travail. L’évolution et la croissance d’un complexe moderne de production intégrée de sucre, d’éthanol, de biogaz, de compost et de cogénération d’électricité à partir de biomasse de canne à sucre, ont été mises en exergue le premier jour tandis que le deuxième était axé sur les petits agriculteurs. L’atelier de travail a conclu que la récente implication accrue des grandes entreprises agroalimentaires améliorera davantage le rythme du changement; que la RD&E doit développer un environnement stimulant pour la recherche novatrice; que les modèles de vulgarisation soient revus pour répondre aux besoins des clients; que les connaissances acquises d’autres industries et multinationales soient intégrées dans le programme de gestion et de recherche; qu’il y a un besoin urgent d’une pépinière de jeunes talents dans la RD&E de la canne à sucre, et que des liens efficaces entre usiniers et agriculteurs, ainsi que leur entière participation et leur soutien, sont essentiels pour un transfert fructueux, rapide et de meilleure qualité des résultats de recherche afin d’assurer la rentabilité et la durabilité de la filière canne.
ANÁLISIS Y TRANSFERENCIA DE TECNOLOGÍA DE INVESTIGACIÓN EFICIENTE UTILIZANDO UN ENFOQUE MULTIDISCIPLINARIO: RESUMEN DEL 3er TALLER DE MANEJO Y TRANSFERENCIA DE TECNOLOGÍA DE LA ISSCT

F.C. BOTHA$^1$ y M.C. GOPINATHAN$^2$

$^1$BSES Limited, Indooroopilly, Australia
$^2$EID Parry (India) Limited, Bangalore, India

PALABRAS CLAVE: R&D Paisaje, Gestión Innovadora, Extensión Modelos, los Agricultores de Pequeña Escala, Producción Mesetas.

Resumen
Este trabajo sintetiza las actividades del Taller de Manejo y Transferencia de Tecnología de la ISSCT que se realizó en Mamallapuram, Tamil Nadu, India del 24 al 27 de agosto de 2011. Las presentaciones se agruparon en cuatro sesiones: extensionismo a productores de pequeña escala; empaque y distribución de la tecnología; manejo de la innovación y la diversificación, manejo de desarrollo de la tecnología y la extensión. En el taller se incluyó una visita de dos días a la región Nellikuppam (100 kilómetros al sur de Mamallapuram), una de las regiones más antiguas de cultivo y procesamiento de caña de azúcar en India. Se resaltó la evolución y el crecimiento de un moderno complejo de bio-fábrica integrada que produce azúcar, etanol, biogás, biosuelo y cogeneración de electricidad de la biomasa cañera; durante el segundo día, el enfoque fue sobre los productores a pequeña escala. En el taller se concluyó que la creciente participación de grandes agro negocios que recién comienza, influirá en el ritmo de cambio. Además, que la I+D necesita desarrollar un ambiente estimulante para la investigación innovadora; que es necesario revisar los modelos de extensionismo para que cumplan con las necesidades de los clientes; que las enseñanzas de otras industrias y empresas multinacionales se integren en el manejo y programa de investigación; que existe una necesidad urgente por un grupo de jóvenes con talento en I+D en caña de azúcar. Finalmente, que las conexiones efectivas entre el ingenio y el productor de caña y su participación y apoyo completos son esenciales para la entrega exitosa de mejores y más rápidos resultados de investigación para garantizar la rentabilidad y sostenibilidad de todas las partes interesadas.
ANÁLISE DE PESQUISA E TRANSFERÊNCIA DE TECNOLOGIA EFICAZES COM O USO DE UMA ABORDAGEM MULTIDISCIPLINAR: UM RESUMO DO 3º WORKSHOP ISSCT DE GERENCIAMENTO E TRANSFERÊNCIA DE TECNOLOGIA

Por

F.C. BOTHA\textsuperscript{1} e M.C. GOPINATHAN\textsuperscript{2}

\textsuperscript{1}BSES Limited, Indooroopilly, Austrália
\textsuperscript{2}EID Parry (India) Limited, Bangalore, Índia

PALAVRAS-CHAVE: Paisagem de R&D, Gestão Inovadora, Modelos de Extensão, a Pequenos Agricultores, Platós de Produção.

Resumo

Este trabalho resumê as atividades do Workshop ISSCT de Gerenciamento e Transferência de Tecnologia, realizado de 24 a 27 de agosto em Mamallapuram, Tamil Nadu, Índia. As apresentações foram agrupadas em quatro sessões: Apresentação de produtores de grande e pequeno porte; embalotamento e entrega de tecnologia; gerenciamento de inovação e diversificação; gerenciamento de desenvolvimento e extensão tecnológicos. O Workshop também ofereceu uma visita de 2 dias à região de Nellikuppam (100 km ao sul de Mamallapuram), uma das áreas mais antigas de cultivo e processamento de cana. Foram enfatizadas a evolução e o crescimento de um moderno complexo integrado de uma biofábrica que produz açúcar, etanol, biogás, bioterra e cogeração de eletricidade a partir da biomassa da cana. Já no segundo dia, o foco voltou-se a pequenos produtores. O workshop concluiu que o crescente envolvimento de grandes empresas de agronegócios acelerará o ritmo das mudanças, que o setor de Pesquisa e Desenvolvimento precisa criar um ambiente para pesquisas inovadoras, que os modelos de extensão devem ser revistos para atender às necessidades do cliente, que os aprendizados de outros setores e multinacionais devem ser integrados o programa de gerenciamento e pesquisa, que existe uma necessidade urgente de formar jovens talentos em Pesquisa e Desenvolvimento em cana-de-açúcar e que as conexões eficazes entre a usina e o produtor e a participação e o apoio desses são essenciais para resultados positivos e para garantir a rentabilidade e a sustentabilidade de todos aqueles envolvidos no processo.