Sugarcane Horticulture and Management
In the Everglades Agricultural Area

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ABSTRACT

Sugarcane (Saccharum officinarum) is the primary crop of the Everglades Agricultural Area (EAA), a designated farming area located in south central Florida. In 2008 and 2009, sugarcane occupied approximately 400,000 of the EAA's 700,000 total acres. This paper provides an overview of sugarcane plant characteristics and the farming practices used by cane producers of the EAA. This report identifies some issues of sugarcane production that affect the environment and proposes elements of a new farming system that would seek to provide a more sustainable agricultural model for the EAA and south Florida. Among the problems of the EAA is soil subsidence (oxidation) that generates losses between 0.5 and 1.5 inches of EAA organic soils per year and results in significant emissions of greenhouse gases and the loss of organic matter. Also the current drainage practices induce nutrient runoff loads to lakes and estuaries, mainly phosphorus leaching. Furthermore, practices like pre-harvest burning of cane fields generates additional carbon emissions. The proposed farming system would store water on sugarcane fields during the rainy season (June to October), thereby reducing impacts to the environment caused by excessive freshwater discharges to coastal estuaries. Certain varieties of sugarcane plant have the ability to survive high water table conditions because they possess a more highly developed aerenchyma, a morphological characteristic that allows gas exchange with the roots. To implement a new sugarcane farming system based on these flood-tolerant sugarcane varieties government researchers must create all the elements of a new farming system, starting with development of the new varieties and continuing on to develop functional modifications to many other farming system components, including field operations scheduling, equipment, fertilization, herbicide/pesticide treatments, ripening and harvest. Another potential element of a more sustainable farming system would be to utilize varieties of sugarcane that can not only survive flood cycles but also absorb greater amounts of phosphorous thereby reducing nutrient loads in drainage waters. Once developed, an extension program for producers would facilitate broad adoption of a high water table practices necessary to store water in a coordinated manner in the EAA.
Sugarcane Horticulture and Management in the EAA

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1-Introduction

The sugarcane is a tropical grass native from Asia, where the sugarcane has been grown in gardens for more than 4,000 years. The product of interbreeding four species of the Saccharum genus, so sugarcane is a giant, robust and sugary plant.

In the past, sugarcane was cultivated to get firm forms were used for construction, softer and juicier forms were for chewing. Around 400 B.C. crude sugar was developed in countries of Asia. After, cane culture was spread to Egypt, and there had built plantations and stone mills. Around 710 A.D. the Egyptians developed clarification, crystallization and refining. By 1493 Colombus introduced sugarcane to America continent. It reached North America in the late 1700s (Kampem, 2002).

Around the world sugar cane is cultivated in areas tropical and sub-tropical. The three countries largest producers are Brazil, India and China in decreasing order of production. The United States occupy the ninth position in the ranking of the country’s largest producers of sugarcane (FAO, 2009), such the Table 1 shows. The features of sugarcane crop allows that the crop is able to grow only in south of United States, where the climate is appropriate for sugar cane. According FAO (2009) the area harvested in the year 2009 was 873,935 acres (353,659 hectares), being that the average productivity was 34 T/ac (77 t/ha).

Table 1 Country’s largest producer of Sugarcane in 2009.

<table>
<thead>
<tr>
<th>Ranking</th>
<th>Country</th>
<th>Million Tons (*)</th>
<th>Area harvested (million acres)</th>
<th>T/ac</th>
<th>Million tonnes</th>
<th>Area harvest (million hectares)</th>
<th>t/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Brazil</td>
<td>758,884</td>
<td>21,090</td>
<td>36</td>
<td>689,895</td>
<td>8,598</td>
<td>80</td>
</tr>
<tr>
<td>2</td>
<td>India</td>
<td>313,531</td>
<td>10,792</td>
<td>29</td>
<td>285,029</td>
<td>4,400</td>
<td>65</td>
</tr>
<tr>
<td>3</td>
<td>China</td>
<td>125,120</td>
<td>3,999</td>
<td>31</td>
<td>113,745</td>
<td>1,630</td>
<td>70</td>
</tr>
<tr>
<td>4</td>
<td>Thailand</td>
<td>73,498</td>
<td>2,287</td>
<td>32</td>
<td>66,816</td>
<td>0,932</td>
<td>72</td>
</tr>
<tr>
<td>5</td>
<td>Mexico</td>
<td>56,217</td>
<td>1,641</td>
<td>34</td>
<td>51,106</td>
<td>0,669</td>
<td>76</td>
</tr>
<tr>
<td>6</td>
<td>Pakistan</td>
<td>55,049</td>
<td>2,523</td>
<td>22</td>
<td>50,045</td>
<td>1,029</td>
<td>49</td>
</tr>
<tr>
<td>7</td>
<td>Colombia</td>
<td>42,350</td>
<td>0,930</td>
<td>45</td>
<td>38,500</td>
<td>0,379</td>
<td>101</td>
</tr>
<tr>
<td>8</td>
<td>Australia</td>
<td>34,602</td>
<td>0,959</td>
<td>36</td>
<td>31,456</td>
<td>0,391</td>
<td>80</td>
</tr>
<tr>
<td>9</td>
<td>United States</td>
<td>30,201</td>
<td>0,867</td>
<td>35</td>
<td>27,455</td>
<td>0,353</td>
<td>78</td>
</tr>
<tr>
<td>10</td>
<td>Philippines</td>
<td>25,226</td>
<td>0,990</td>
<td>25</td>
<td>22,932</td>
<td>0,404</td>
<td>57</td>
</tr>
</tbody>
</table>

Sugarcane has been used as a feedstock for three main products around the world: sugar, ethanol, and co-generation of electricity. In the United States, sugarcane has been used only for sugar production and co-generation of electricity in the mills. Nowadays, the sugarcane crop is present in greater quantity in four states in the south of the United States, Florida, Hawaii, Louisiana, and Texas (USDA, 2002). Florida was responsible for 400,000 acres (988,000 hectares) planted in 2008/2009. The Palm Beach County account with 75% percent acreage in Florida, other counties like Hendry, Glades, and Martin produced commercially sugarcane too (Baucum and Rice, 2009). Other crops such as winter vegetables, sod, and rice grown on a lesser scale.

Florida is produced 48% of sugar cane and around 24% of sugar produced in the United States. There are two fonts to do sugar in the United States, beets and sugarcane. States like Minnesota, North Dakota, Michigan, Idaho, and California contributed with sugar from beets in 50%, another 50% is from sugarcane.

The characteristics found in the ecosystem of the State of Florida, specific in the Everglades Agricultural Area (EAA) make the sugar cane a viable crop for this region.

The demands to achieve a good production of sugarcane depend on the integration of several factors such as climate, soil, and crop management. But besides that, there is considerable concern in production with sustainability for the ecosystem to be preserved. The guides and factors that affect the sustainability of the system will be presented.

2-General Sugarcane Horticulture

2.1-Botany Sugarcane

Botanically, sugarcane belongs to the Andropogonae tribe of the family Gramineae, order Glumiflorae, class Monocotyledoneae, subdivision Angiospermae, division Embryophita siphonogama. The subtribe is Sacharae and the genus, of course, Saccharum, derived from the Sanskrit "sarkara = white sugar", a reminder that the plant reached the Mediterranean region from India.

The sugarcane production consist of good plant development, therefore is essential knows sugarcane botany to apply a great management. The main parts of the sugarcane plant are the stalk, leaf, and root system (see Figure 1).
The stalk (see Figure 2) consists of segments called joints, each joint is made up of a node and an internode. The node is where the leaf attaches to the stalk and where the buds and root primordia are found. A leaf scar can be found at the node when the leaf drops off the plant. Characteristics as the length and diameter of the joints vary widely with different varieties and growing conditions. In general, however, the joints at the base are short and intermodal length gradually increases.

The buds, located in the root band of the node, are embryonic shoots consisting of a miniature stalk with small leaves. The outer small leaves are in the form of scales. The outermost bud scale has the form of a hood. Normally, one bud is present on each node and they alternate between one sides of the stalk to the other. Variations in size shape and other characteristics of the bud provide a means of distinguishing between varieties. The root band also contains loosely defined rows of root primordia. Each primordium exhibits a dark center, which is a root cap, and a light colored "halo."

The 1/3 top of the stalk contains many buds and good supply of nutrients which feed seed cane when it’s planting (Miller and Gilbert, 2009). However, the top of the stalk is relatively low in sucrose and therefore is of little value to the mill early in the harvest season.
Two types of cracks are sometimes found on the surface of the stalk; harmless, small corky cracks which are restricted to the epidermis and growth cracks which may be deep and run the whole length of the internode. Growth cracks are harmful since they allow increased water loss and expose the stalk to disease organisms and insects. Growth cracks are dependent on variety and growing conditions.

The leaf (see Figure 3) is composed of two parts: sheath and blade, separated by a blade joint. The sheath, as its name implies, completely sheaths the stalk, extending over at least one complete internode. The leaves are usually attached alternately to the nodes, thus forming two ranks on opposite sides. The mature sugarcane plant has an average total upper leaf surface of about 0.5 square meters and the number of green leaves per stalk is around ten, depending on variety and growing conditions.

![Figure 3. Parts of sugarcane leaf (Miller & Gilbert, 2009).](image)

The blade joint is where two wedge-shaped areas called "dewlaps" are found. The "top visible dewlap" leaf is a diagnostic tissue that is frequently used in nutritional studies.

There are two kinds of roots that will be developing from seed piece: the set roots, which arise from the root band, are thin and highly branched; the shoot roots, originating from the lower root bands of the shoots, are thick, fleshy and less branched (see Figure 4).

Before shoots form, the germinating seed piece must depend entirely on the set roots for water and nutrients. The set roots, however, are only temporary and their function will eventually be taken over by the shoot roots as they develop. The life of the shoot root is also limited. Each new tiller (shoot) will develop its own roots that eventually take over the function of the original shoot roots. This rejuvenation, governed by the periodicity of tillering, is important because it allows the plant to adjust to changing environmental conditions.
2.2-Physiologic Sugarcane

Sugarcane physiologic is similar to other gramineas, but has capacity to store sucrose in the stalk and it is the harvested economic product. The long growth duration of sugarcane and its tolerance to fluctuating water tables mimic the native sawgrass vegetation and make sugarcane particularly well-suited for the Everglades Agricultural Area of Florida (Miller and Gilbert, 2009).

Sugarcane is a graminea that when planted begin a great tillering in the initial growth phase. After the crop establishment low light or shadow is the main factor that affects vegetative growth, with intense sun lights sugarcane gets the development, tillering and grand growth. By considering sugarcane photosynthetic metabolism C4, it is very efficiency to take sun light energy and to convert for chemical energy.

The sugarcane varieties characteristics determine the stalks numbers, height, stalk diameter, length and width of leaves, and also plant architecture (Rodrigues, 1995), but management and practices influence the development and finally, productivity. Actually, the final yield is a factors combination of variety, management and environment.

The formation of stool is important to increase the numbers of stalks. News shoots grow from buds form at teach stalk joint. Existing buds on adjacent nodes located on opposite sides of the stalks, so after several weeks, these newly formed buds, located 3-7 inches underground will sprout, forming secondary shoots.

These shoots in turn will form buds that produce tertiary shoots. These secondary and tertiary shoots are called tillers, and the primary shoot plus all of the tillers are called the stool.

The development of the root system is important because it has two functions for the sugarcane, first it enables the intake of water and nutrients from the soil and second it is like as reserve of feed.

The growth of the cane plant starts slowly in the germinating bud and it increase gradually until a maximum is reached, which is followed by a gradual decrease. The
name for rapidly growth is “grand growth period”. The Figure 5, adapted from University of Florida (Miller and Gilbert, 2009) illustrious how the growth happen.

![Cane plant growth](image)

Figure 5. Cane plant growth (Miller & Gilbert, 2009).

Ideal conditions of nutrition, moisture, light are essentials for good development, the figure above shows that the monthly increment is higher after 5 or 6 planting the sugarcane piece.

The first growth of seed cane is called plant cane crop. The first harvest occurs after 13 or 15 months planting, as sugarcane crop can emerge again, the next harvest will be around 12 months after and so successively. Although, productivity decrease with the age of ratoons, is an option for the farms to do the planting again or keep the ratoon. This decision is influenced by fertilizes and sugarcane prices.

The inflorescence happens when the plant achieved a development stage and the surround is favorable, as photoperiod and temperatures. Generally, a day length close to 12.5 hours and night temperatures between 68 and 77 °F (20 and 25 °C) will induce floral initiation. Temperatures that are too low and/or water stress inhibit inflorescence development. Nighttime temperatures are generally too low to produce viable sugarcane seed in Florida.

However, the inflorescence is important to search and create news varieties of sugarcane. Research programs use tools to induce the inflorescence and thus, can realize the crossbreeding. The inflorescence, or tassle, of sugarcane is an open-branched panicle. Each tassle consists of several thousand tiny flowers, each capable of producing one seed. The seeds are extremely small and weigh approximately 250 per gram or 113,500 per pound (Miller and Gilbert, 2009).
For commercial sugarcane production, inflorescence development is of little economic importance because when the plant emits the inflorescence the sucrose decreased in the stalks, and this is undesirable to commercial sugarcane crops.

2.3-Required temperatures

The temperatures are high important to sugarcane production, the plant is tolerant to high temperatures, growing with summer average temperatures, around 116 °F or 47°C (with irrigation) and under 70 °F or 21°C, but lower temperatures get down stalk growth and promote sucrose storage (Rodrigues, 1995).

Sugarcane cultivation has a wide latitude band around the world, since 35°N till 30°S, the heigh can range from sea level to 3,280 feet (1,000 m).

Frost can damage sugarcane because ice is created between cellular spaces, but that depends of temperatures values, low temperatures duration and frost duration. Is recommended harvest as soon as possible the stalks after frosts to make a good use of remainder sugar.

After planting, during germination temperatures between 89 and 100 °F (32 to 38 °C) are optimum. For growth, daily temperatures from 72 to 86 °F (22 to 30 °C) is good for growth sugarcane, but temperatures below 68 °F (20 °C) can stop the sugarcane growth. However, to start the ripening phase is desirable lower temperatures, that is because stress temperatures support sucrose accumulation in the stalks, so around 68 to 50 °F (20 to 10 °C) is suitable for maturation.

2.4-Required water

The water requirement to sugarcane production can differ with the growth phases and also depends on climate, to know exactly how much is necessary per growth phase is necessary crop coefficient values (kc), relating maximum evapotranspiration (ETm) to reference evapotranspiration (ETo).

Water requirements (ETm) of sugarcane are 59 to 79 inches (1500 to 2500 mm) evenly distributed over the growing season. In the following table are presented the duration to each growth phases and reference kc (FAO Water, 2010).
Table 2 Water requirement

<table>
<thead>
<tr>
<th>Development stages</th>
<th>Days for world varieties</th>
<th>Kc coefficients*</th>
</tr>
</thead>
<tbody>
<tr>
<td>planting to 0.25 full canopy</td>
<td>30-60</td>
<td>0.45-0.6</td>
</tr>
<tr>
<td>0.25 to 0.5 full canopy</td>
<td>30-40</td>
<td>0.75-0.85</td>
</tr>
<tr>
<td>0.50 to 0.75 full canopy</td>
<td>15-25</td>
<td>0.90-1.00</td>
</tr>
<tr>
<td>0.75 to full canopy</td>
<td>45-55</td>
<td>1.00-1.20</td>
</tr>
<tr>
<td>peak use</td>
<td>180-330</td>
<td>1.05-1.30</td>
</tr>
<tr>
<td>early senescence</td>
<td>30-150</td>
<td>0.80-1.05</td>
</tr>
<tr>
<td>Ripening</td>
<td>30-60</td>
<td>0.60-0.75</td>
</tr>
</tbody>
</table>

* Kc values depend on minimum relative humidity and wind velocity


2.5-Nutrition

Basically, sugarcane crop demands macronutrients (N, P, K, Ca, Mg, S) and micronutrients (B, Cl, Cu, Fe, Mn, Mo and Zn) to growth healthy likes others crops. Also exist "functional" or "beneficial" elements as Silicon (Si) and it can increase yields.

The sugarcane crop consumes specific quantities from the soil to determined production, in Brazilians fields the extraction of nutrients to produce 100 tons (US short tons) per hectare is shows in the table below.

Table 3 Extraction and exportation of macronutrients to produced 100 Tons of stalks

<table>
<thead>
<tr>
<th>Parts of plant</th>
<th>N</th>
<th>P</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>lbs/100T (kg/100t)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stalks</td>
<td>166 (83)</td>
<td>22 (11)</td>
<td>156 (78)</td>
<td>94 (47)</td>
<td>66 (33)</td>
<td>52 (26)</td>
</tr>
<tr>
<td>Leaves</td>
<td>120 (60)</td>
<td>16 (8)</td>
<td>192 (96)</td>
<td>80 (40)</td>
<td>32 (16)</td>
<td>36 (18)</td>
</tr>
<tr>
<td>Total</td>
<td>286 (143)</td>
<td>38 (19)</td>
<td>348 (174)</td>
<td>174 (87)</td>
<td>98 (49)</td>
<td>88 (44)</td>
</tr>
</tbody>
</table>

Thus, grounded in the productive desirable and soil or leaf analysis, is possible to estimate the necessary quantity to add in the planting.

Each nutrient is responsible to affect the development of sugarcane, as nitrogen, it has the greatest influence on cane ripening of all the nutrient elements. Cane will store a higher percent of sucrose when nitrogen is limited 6 to 8 weeks prior to harvest. Although a late-season nitrogen deficiency can actually promote improved sugarcane ripening, this scenario is unlikely to be achievable on organic soils because nitrogen rates are highs all the seasons.

3-EAA Sugarcane Farming Practices

3.1-EAA characteristics

The Everglades Agricultural Area (see Figure 6) is localized in the southeast region of Florida State, covers an area of 1113 mi² (2883 km²) around Lake Okeechobee.

Figure 6. EAA map

Sugarcane is planted in approximately 56% (400,000 acres or 161,880 ha) of EAA without account the crop rotation and there found ideal conditions of temperatures and required water supply. Furthermore, other crops such as winter vegetables, sod and rice
have been planted on a lesser scale (Daroub et al, 2008), approximately 300,000 acres (121,400 ha).

3.1.1-Climate

The rainfall is described for a wet summer and dry winter (see fig. 7). The most of the rain occurs from June until October with approximately 35 inches (889 mm). The other period, from November to May is dryer and corresponds by 18 inches (457 mm).

![Figure 7. Monthly precipitation from Belle Glade Station (Climate Charts, 2010).](image)

Sugarcane growth phases require different temperatures during germination, growth and ripening and the growers have to take attention with the weather to avoid damages in the field. During the year the averages from Belle Glade Station are in the figure below (see Figure 8).
3.1.2 - Soils

In the Everglades Agricultural Area soils are physically, chemically and morphologically diverse. The most of the soils comes from decomposition of organic matter, saw grass and other plants and this soil is called “muck soils”, this soil is responsible to occupy around 80% of sugarcane agricultural land. Another part of the land with sugarcane crop the soil is called as sandy soil, and it takes a place around 20% (Gilbert et al, 2008) for sugarcane production.

Thus, the management of sugarcane grown, as the addition of nutrients, crop rotation and environmental issues depending of soil characteristics found by Florida producers.

3.1.2.1 - Organic

Organic or “muck” soils present in the EAA is classified in the order Histosols, suborder Saprits and group Haplusaprits. Histosols are present greatly state of Florida as Figure x shows. Depending of degree decomposition, mineral or clay content, depth to bedrock or mineral horizon and content of organic matter Haplusaprits are classified in different classes (Gilbert & Rice, 2009).
Organic soils used for sugarcane production are the most black in color, generally characterized by high organic matter content, around 85%, low clay mineral content, with different depths, but when drainage organic matter is oxidized and soil subsidence achieves 0.5 to 1.5 inches per year (1.3 to 3.8 cm per year). Therefore, soil depth has changed and it results in a transitioning to a different soil classification (Gilbert & Rice, 2009), for example, the depth of the organic material generally decreases with distance from Lake Okeechobee (Wright & Hanlon, 2009).

The organic soils is on continue transition because organic matter contents decline with aerobic environment and artificially tools, like drainage, accelerates the soil subsidence process because keep the soil under aerobic mineralization. As subsidence (soil oxidation and loss of depth) progresses, the soil organic layer decreases, ultimately changing to the next shallower soil series. For example, Lauderhill would be expected to become Dania with time (Table 4).
Table 4 Summary of characteristics of EAA Histosols.

<table>
<thead>
<tr>
<th>Soil Series</th>
<th>Mineral Content (%)</th>
<th>Thickness of organic layer (inches)</th>
<th>Underlying material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Torry</td>
<td>&gt; 35</td>
<td>&gt; 51</td>
<td>Limestone</td>
</tr>
<tr>
<td>Terra Ceia</td>
<td>&lt; 35</td>
<td>&gt; 51</td>
<td>Limestone</td>
</tr>
<tr>
<td>Pahokee</td>
<td>&lt; 35</td>
<td>36-51</td>
<td>Limestone</td>
</tr>
<tr>
<td>Lauderhill</td>
<td>&lt; 35</td>
<td>20-36</td>
<td>Limestone</td>
</tr>
<tr>
<td>Dania</td>
<td>&lt; 35</td>
<td>&lt; 20</td>
<td>Limestone</td>
</tr>
<tr>
<td>Okeechobee</td>
<td>&lt; 35</td>
<td>&gt; 51</td>
<td>Limestone</td>
</tr>
<tr>
<td>Okeelanta</td>
<td>&lt; 35</td>
<td>16-40</td>
<td>Sand</td>
</tr>
</tbody>
</table>

(Snyder, 2005)

Agricultural managements should be done to impair soil subsidence and in this way produce with sustainability. If the producers avoid the soil subsidence the soil deep is preserved and they can cultivate the same land for a long time.

3.1.2.2-Sand

The classification for sandy soils in the EAA is order Spodosols, suborder Aquods, groups Alaquods, but the classes are high diversified, even though organic matter content is low in the most of sandy soils (USDA, 1999).

The presence of Spodosols, suborder Aquods, is greatly in Florida, dividing space of land with Histosols (see Figure 10).
Generally, sandy soils are responsible to low productivity because are poor in nutrients and requires large fertilizers inputs. However, fertilizers inputs increase the costs to produce sugarcane and contribute to release nutrients when the soil is drained.

Characteristics as such organic matter content, pH, depth and estimated sugarcane yield are present in the table below for each sandy soil series in the EAA.
Table 5 Properties of sandy soils used for sugarcane production.

<table>
<thead>
<tr>
<th>Soil Series</th>
<th>Depth (inches)</th>
<th>CEC(^1) (meq/100g)</th>
<th>BS(^2)</th>
<th>OC(^3)</th>
<th>pH Range</th>
<th>Depth to Restrictive Layer (inches)</th>
<th>Estimated Sugarcane Yields (tons/acre)(^4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basinger</td>
<td>0 - 4</td>
<td>0.8</td>
<td>25</td>
<td>-</td>
<td>4.5 - 7.8</td>
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<tr>
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<td>4 - 25</td>
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<td>-</td>
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<td>-</td>
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<td>47 - 60</td>
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<td>67</td>
<td>0.2</td>
<td>6.4 - 8.4</td>
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<td>73</td>
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<tr>
<td></td>
<td>4 - 37</td>
<td>1.5</td>
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<td></td>
<td>37 - 79</td>
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<td>2.2</td>
<td>47</td>
<td>1.4</td>
<td>4.5 - 6.5</td>
<td>26</td>
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<td>7 - 26</td>
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<tr>
<td></td>
<td>26 - 47</td>
<td>6.2</td>
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<td>1.7</td>
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<td>Oldsmar</td>
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<td>4.9</td>
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<td></td>
<td>16 - 37</td>
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<td>4.4 - 5.3</td>
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<td>4.7 - 7.1</td>
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<tr>
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<td>4.6 - 6.9</td>
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<td>1.4</td>
<td>5.9 - 7.2</td>
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<td>45</td>
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<tr>
<td></td>
<td>2 - 7</td>
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<td>5.5 - 6.9</td>
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<td></td>
<td>7 - 20</td>
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<td>8</td>
<td>-</td>
<td>3.6 - 6.5</td>
<td>22</td>
<td>45</td>
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<tr>
<td></td>
<td>8 - 22</td>
<td>0.1</td>
<td>-</td>
<td>-</td>
<td>3.6 - 6.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>22 - 38</td>
<td>20.2</td>
<td>59</td>
<td>-</td>
<td>5.1 - 7.6</td>
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<td></td>
</tr>
</tbody>
</table>

(Gilbert & Rice, 2008).\(^1\) CEC = Cation Exchange Capacity (average to depth indicated); \(^2\) BS = Percent Base Saturation (average to depth indicated); \(^3\) OC = Percent Organic Carbon (average to depth indicated); \(^4\) Sugarcane yields given are estimates under good management practices and may vary with variations in climate and management practices. They reflect the relative productive capacity of each soil.
The sustainable management in that soil to produce sugarcane requires attention to practices that keep high content of organic matter to improve many aspects as such water holding capacity, tilth, decrease erosion potential and increase cation-exchange capacity. These sustainable practices to hold organic matter in the field can be plow down the crop rotation, avoid sugarcane burned, additions of organic composts (Muchovej et al, 2008).

3.2-Crop development

3.2.1-Planting

The planned planting should be done previously, so that the soil will be ready to receive the seed cane and variety of cane area chosen to be the ideal. Before planting, must be made to analyze the soil to be sure there will not waste and no lack of nutrients available to plants.

The addition of nutrients can be done at planting, but if it is necessary to make corrections in soil, like soil pH – ideal between 5.5-6.5 – it should be done previously.

The commercial plantation of sugarcane in the farms around the world has been done with stalks. A favorable sugarcane variety is planted by using sections of stalks from the mother plant, which then sprout daughter plants (clones) and are genetically identical to the mother plant variety. This process is called vegetative propagation, in this way the production of sugar cane is uniform.

In the Everglades Agricultural Area the sugarcane planting takes place from late August through January. But in North of Florida sugarcane can be planted between mid-August and mid-September and also have another option, is to plant after mid-November, so buds remain dormant during the winter and in the spring occur germination (Bacum et al. 2009).

Manual planting has been used yet, despite of high labor prices. The retirement of stalks to seed cane is different than to harvest to the mill, is important take care with the stalks. In this situation is recommended to do manual harvest.

The propagation vegetative consists to take stalks of mature sugarcane in the reserved field. The stalks of seed cane are mechanically or manually harvested, loaded onto wagons, transported to the field target and dropped into the furrow. Each seed cane has around 2-6 inches (5-15cm) with at least two buds. The shallow furrows roughly 3-8 inches (8-20 cm) deep. Generally, the seed cane is dropped as pairs, for a double line of sugarcane stalks throughout the furrow, but can be also planted as a single row, the spacing can differ at fields.

For commercial sugarcane row spacing is between 4-10 feet (1.2 - 3.0 m), but the most used is 5 feet (1.5m) according required mechanical harvest (Bacum & Rice,
Within two or three weeks, under favorable conditions, soil temperature and moisture, shoots emerge and produce secondary shoots to give a dense stand of cane.

A sunny location is advice to growth sugarcane, and this characteristic is found in the EAA, shadow can decrease the productive potential. However, the field should be dry during the first three weeks after planting, flooded conditions can kill germinating buds and new shoots, so is important to keep available conditions with a good water management require (Bacum et al, 2009).

3.2.2-Growth phases

After germination sugarcane varieties with high tillering and fast growth is desirable to avoid competition with weeds. However, the growth depends of light, temperature, nutrition, moisture and spacing of the plants, so with different periods of planting, the varieties will response also different.

Growth characteristics can differ widely with each variety, but currently the first period is the tillering that achieve the peak around 200 days after planting, second is the “grand” growth when the stalks get higher and the last phase for commercial sugarcane is ripening, when sugarcane accumulates sucrose equable in the stalk, which have 2 months of duration. Experiments done from University of Florida (Miller & Gilbert, 2009) have shown that light is the most significant to increase tillering. Also, with tillering the rows get closed and there is natural weed control.

So, if the producer plants variety sugarcane during September, it will reach the maximum growth increment after six months, around March (see Figure 9).

Figure 11. Sugarcane monthly growth increment with supposed September planting
The knowledge about sugarcane growth phases allows growers to understand the management of nutrients and water tables in the EAA. As talked previous, if the peak of water usage is during the maximum growth, the water tables can be increased during that period, also is possible planning the time correct to turn shallower water tables.

### 3.2.3-Ripening

Ripening is important process that increases sucrose content in the stalks. Thus, sugarcane achieves the maturation time and can be harvested. This process happens in a joint to joint and depends on their age. In young plants the most of sucrose contents is stalks located near at soil level. In maturated plants turns more uniform and distributed in all stool, but the top few internodes sucrose content is lower.

Natural ripening occurs with water, nutrient or temperature stress, without those conditions farmers can apply ripeners that are chemical products to start plant stress, thus fill the stalk with uniform distribution sucrose.

The ripeners are used in Florida to increase sucrose content when natural conditions are not concern with ripening. Apply ripeners is a way to start sugarcane maturation in the moment desirable (Miller & Gilbert, 2009), but does not mean that sugarcane will get more sucrose content than natural ripening.

### 3.2.4-Harvest

The harvest occurs from October through mid-April. The moment to harvest the sugarcane can be decided with the analysis of sucrose content in the stalks, varieties differ the moment has reached maximum yield.

To keep high yield is interesting schedule the harvest with the variety in the optimal time. Thus chose varieties that can best be harvested in early-, mid-, and late-season. This is tool also can optimize the use of machines.

Years ago, sugarcane was hand-harvested, using cane knives, but the conversion to mechanical harvesting began in the mid-1980s and by 1993 the entire South Florida sugarcane crop harvested mechanically. (Bacum et al, 2006).

At harvest the field should be dry itself sufficient for the entry machinery. If the harvested occur with flooded field some damage achieve the plant and performance of machines is reduced.

In some cases the sugarcane is burned before harvest, for example, when there is so much biomass or dead leaves. This, can impede the harvest operation, increase transportation costs to the mill, interfere with milling machinery, and absorb sugar during the extraction process.
After the sugarcane fields are burned, mechanical harvesters deposit the cut cane directly into field wagons. Four-wheel drive tractors haul 16 tons of cane out of the field with each four-wagon load. At special ramps near the field, the cane is dumped from the wagon into highway trailers or rail cars for transport to the mills. Rail cars carry 25-30 tons each. Highway trailers carry 20 tons per load (Bacum et al, 2006).

Sugarcane is a multi-year crop, and the harvested stool is the site for next year's re-growth. New primary shoots emerge each year from the basal (bottom or lower) buds on stools that remain from last year’s growth. Over time, this growth and re-growth pattern gradually elevates the crown of the stool and expands the stool's circumference. However, while the stool typically gets bigger over time, the combined effects of winter and mechanical damage lead to declining basal-bud viability.

So every each 5-10 years sugarcane is replanted, but it’s depending of varieties, some varieties have to be replanted more often to keep the yield. Usually in the EAA sugarcane is replanted fourth year after harvest or after crop rotation harvest.

### 3.3-Nutrition

The growers can use nutrients management available for sugarcane like a strategy to improve the production and quality. In the Florida sugarcane industry, elements that are of nutritional concern include N, P, K, Mg, B, Cu, Fe, Mn, Si, and Zn, but the fertilizer addition has to be efficient. Therefore, the Best Management Practices (BMP) recommends growers to do soil testing, using split applications of nutrients when practical, and applying fertilizers at rates that are consistent with soil test results and realistic yield expectations (Rice et al, 2010).

The soil testing for sugarcane in Florida is conducted by Everglades Soil Testing Laboratory at the UF/IFAS Everglades Research and Education Center (EREC) in Belle Glade.

When the sugarcane crop is already installed in the field, the growers can do the leaf test to identify the deficient nutrients in the plant. The plant-tissue testing in fact is useful to balance micronutrients and results relate the nutrients with optimal yield in databases.

#### 3.3.1-Organic soils

The availability of nutrients to the sugarcane uptake during the grown differs in each soil. As organic soils have a lot of organic matter, there are highs rates of the mains nutrients requests for the plant. But the land management influencing the forms and leaching of nutrients.

Organic soils in EAA have around 2-4% nitrogen content (Porter and Sanchez, 1994). However, drainage of soil resulted in oxidation of a large quantity of organic
nitrogen. The main action has coming from microbial oxidation and it is responsible for 50 to 75% of soil subsidence.

The quantity of nitrogen in organic soils is enough to supply the necessaries of sugarcane crop, and the most important is reducing the loss from oxidation and runoff waters.

Some growers have applied N during mid-December through February for the plant or ratoon crop, when the soils are cool and moist. Application of N during this period can result in succulent leaf growth and may increase the risk of frost-damage should temperatures fall below 32° F.

The plants are able to uptake the nitrogen when it is mineralized. A deficiency may appear if organic nitrogen cannot be mineralized under unfavorable conditions, such as flood. In EAA, young sugarcane plants grown on shallow mucks during cool and in the wet periods, have shown nitrogen deficiency symptoms.

Thus, addition of nitrogen fertilizer is not recommended in organic soils (Gilbert & Rice, 2009).

The phosphorus is usually request in organic soils for a good yield. Control the quantity available for the sugarcane plant and after roots is important because the deficient tends increase with crop age (Rice et al, 2010).

In the sugarcane planting Everglades Soil Testing Laboratory recommends amounts range from 0 to 33 lb P/ac (0 to 75 lb P₂O₅/ac) for plant cane and first ratoon crops, 0 to 31 lb P/ac (0 to 70 lb P₂O₅/ac) for second ratoon, and 18 lb P/A (40 lb P₂O₅/ac) for subsequent ratoons.

However, phosphorus can be leaching with waters runs off. The water in EAA has highs ranges of phosphorus because the drainage of fields take off amounts of phosphorus every time when the water is pumped, the consequence is affecting the ecosystem and water quality.

The potassium is nutrient very mobile in the soil and plant and sugarcane crop absorbs large quantities in their development. In organic soils there not a deficiency if the field is not drainage with frequency.

The inputs of main nutrients (nitrogen, phosphorus and potassium) in organic soils range between values, depending of soil test. In the table below, the ranges is showed.
The deficiency of calcium rarely occurs in organic soils in the EAA, the most of the Histosols in Florida overlay limestone bedrock, and calcium is moved into the surface soil profile by diffusion and mass flow with soil water.

Sometimes, when the organic soil is acid the sugarcane can be deficient in magnesium, but is rarely. Highs rates of potassium can promote the magnesium deficiency symptoms. However, the management of magnesium rates in the plant can be done if leaf analysis.

In organic soils the sulfur is present in quantities enough for sugarcane grown and soil microorganisms can oxidize elemental sulfur and organic sulfur compounds into sulfate forms that are available for the plant uptake. There are others ways to increase the sulfur in the soil, as fertilizers blends used to deliver nitrogen, potassium, phosphorus or manganese to the crop use sulfate sources. Also, sulfur is present in the atmosphere as sulfur dioxide or sulfur trioxide, which is able to enter in the soil-water through rainfall.

Another form to improve the sulfur in the soil is when the pH exceed 6.6 and is recommended to input elemental sulfur directly in the furrow at planting, thus the soil is acidifying and micronutrients turns available.

Elemental sulfur rates are currently under study for sugarcane on organic soils. Environmental issues should also be considered since environmental sulfur has been linked to sulfate-reducing bacteria (i.e., they use specific sulfur compounds as an energy source) that catalyze mercury transformations in wetland ecosystems.

In organic soils strategies as crop rotation can be used to improve or keep the nutrients in the soil, also crop rotation contribute with soil conservation. The crops able to do rotation with sugarcane crop will be show in other topic.

---

**Table 6 Fertilizers inputs in organic soils**

<table>
<thead>
<tr>
<th>Phases</th>
<th>N</th>
<th>P</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cane plant</td>
<td>-</td>
<td>33 (37)</td>
<td>208 (233)</td>
</tr>
<tr>
<td>First ratoon</td>
<td>-</td>
<td>33 (37)</td>
<td>208 (233)</td>
</tr>
<tr>
<td>Second ratoon</td>
<td>-</td>
<td>31 (35)</td>
<td>125 (140)</td>
</tr>
<tr>
<td>Terciary ratoon</td>
<td>-</td>
<td>18 (20)</td>
<td>125 (140)</td>
</tr>
</tbody>
</table>

3.3.2-Sand soils

Sandy soils contains variable rates of organic matter, in the most of the sandy soils the nutrient content and water holding capacity is low.

Nitrogen deficiencies can readily occur in sugarcane grown on sandy soils. The applications or nitrogen fertilizer are often required during the growing season to sustain adequate sugarcane production. One way to do input nitrogen fertilizer with efficiency is apply multiple split-applications in order to minimize nitrogen losses and maximize the nitrogen-supply to plant roots.

In the hot-humid summer found in Florida, the applications of nitrogen fertilizer can be lost in parts by leaching below the root zone of these marginal sandy soils or due to denitrification, and thus become unavailable to the sugarcane plant.

UF/IFAS supports that the growers use split-application to improve nitrogen use fertilizer, but that is option and depends about the prices of fertilizers and fuel costs, the labor is more to do this application. Therefore, generally is recommending input 180 lb N/ac (90 kg N/ha) in the first year crop cycle. Sandy soils with more organic matter, as such mucky sands are recommended amounts of 110 lb N/ac (55 kg N/ha) and for sandy mucks are 30 lb N/ac (15 kg N/ha).

Mineral soils, like sandy soils need applications of phosphorus every year. But is important to keep in mind that excess of phosphorus can be leaching with drainage and water runs off, so apply only the necessary for the sugarcane crop is enough. The quantities for the sandy soils are recommended by UF/IFAS are the same to organic soils in EAA.

In soils well-drained, coarse and sandy soils, may occur same potassium deficiency occasioned by high mobility of potassium in the soil (Gilbert & Rice, 2009). The quantities usually inputs by the growers in EAA are around from 0 to 208 lb K/ac (0 to 250 lb K₂O/ac) for plant cane and first ratoon crops, and 0 to 125 lb K/ac (0 to 150 lb K₂O/ac) for second ratoon and all subsequent ratoon crops.
Table 7 Fertilizers inputs in sand soils

<table>
<thead>
<tr>
<th>Phases</th>
<th>N</th>
<th>P</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cane plant</td>
<td>180 (202)</td>
<td>33 (37)</td>
<td>208 (233)</td>
</tr>
<tr>
<td>First ratoon</td>
<td>180 (202)</td>
<td>33 (37)</td>
<td>208 (233)</td>
</tr>
<tr>
<td>Second ratoon</td>
<td>180 (202)</td>
<td>31 (35)</td>
<td>125 (140)</td>
</tr>
<tr>
<td>Terciary ratoon</td>
<td>180 (202)</td>
<td>18 (20)</td>
<td>125 (140)</td>
</tr>
</tbody>
</table>


Calcium, sulfur and magnesium are not requested with frequency in sand soils, but likes macronutrients is important to follow the recommends through the soil or leaf analysis.

3.4-Nutrients leaching

Soil, water and nutrients applied on the cane field have a dynamic and should be controlled to avoid water contamination, influencing natural ecosystem in the EAA.

Phosphorous leaching can occur as either particulate or soluble materials (Daroub et al., 2008). Orthophosphate ($\text{PO}_4^{3-}$) and soluble organics are soluble forms of P that are released by mineralization of the organic soils of the EAA or that are added as fertilizer. Orthophosphates are quite reactive, in the appropriate form for plant uptake, and may leach in drainage water. For this reason, many Best Management Practices (BMPs) have been implemented to address fertilizer-derived P leaching.

Morris (1975) estimated that soil oxidation accounted for releases of 77 lbs P per acre per year (87 kg P ha/yr), and Reddy (1987) reported that oxidation caused P releases ranging from 34 to 164 lbs P per acre per year (38 to 185 kg ha/yr).

For nitrogen, the leaching happens in the same way for phosphorus inclining to increase the leaching between August and September (CH2M-Hill, 1978) when the rainfall is high and farmers applies drainage on the fields. As Histosols has a great amount of nitrogen, is not necessary add nitrogen fertilizers frequently and growers using sand soils should follow BMPs to reduce lacks.

According Gilbert & Rice (2009) the loss of nitrogen mineralization can be between 320 to 1340 lbs per acre per year (160 to 670 kg/ha/yr.) and loss from runoff
waters of agricultural areas, around 11 a 36 lbs N per acre per year (5 to 18 kg N/ha/yr.) left the field.

3.5-Varieties

All the principal varieties, which occupy more than 1.0% of land in the EAA, are developed by a cooperative program based at Canal Point, Florida. The United States Department of Agriculture, Agricultural Research Service; the University of Florida/Institute of Food and Agricultural Sciences; and the Florida Sugar Cane League, Inc. participate in this cooperative program at Canal Point.

In the EAA there 21 commercial sugarcane varieties planted during 2008, each one have a best period to be harvested. Also, according sugarcane varieties census (Glaz B. et al, 2009) during 2008 the six more planted in decrease order were: CP 89-2143, CP 88-1762, CP 80-1743, CP 78-1628, CP 72-2086 and CP 84-1198. Other varieties occupied less than 1.0% of land in the EAA.

Below we can see on the table the area occupied by each variety and the better period to harvest according the moment that accumulates maximum sucrose.

Table 8 Varieties planted in the EAA and recommended period harvest.

<table>
<thead>
<tr>
<th>EAA occupied (%)</th>
<th>Variety</th>
<th>Oct 1</th>
<th>Oct 2</th>
<th>Nov 1</th>
<th>Nov 2</th>
<th>Dec 1</th>
<th>Dec 2</th>
<th>Jan 1</th>
<th>Jan 2</th>
<th>Feb 1</th>
<th>Feb 2</th>
<th>Mar 1</th>
<th>Mar 2</th>
<th>Apr 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>31</td>
<td>CP 89-2143</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>20</td>
<td>CP 88-1762</td>
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<tr>
<td>19</td>
<td>CP 80-1743</td>
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<tr>
<td>11</td>
<td>CP 78-1628</td>
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<tr>
<td>3.8</td>
<td>CP 72-2086</td>
<td></td>
<td></td>
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<tr>
<td>3.6</td>
<td>CP 84-1198</td>
<td></td>
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</tbody>
</table>

3.6-Weed control

Weed control is necessary to avoid competition between sugarcane and weeds. A good stand of sugarcane that emerges rapidly and uniformly and forms a complete canopy that shades the row middles early in the season is very helpful in reducing weed competition, but the loss of cane stools during the ratoon, harvest damages or insects can create spaces to growth weeds.
High weed infestations further competition with sugarcane crop, can also interfere with sugarcane harvest by adding unnecessary harvesting expenses, and allowed weed to mature and produce seeds will keep problems for future years.

According reported by University of Florida the mains weed species found sugarcane fields in the EAA are Napiergrass (*Pennisetum purpureum* Schumacher) and Fall panicum (*Panicum dichotomiflorum*).

Herbicides applications is the main solution to avoid weed development on the fields, but also is important keep in mind the use of single product or chemical group product can enhance weed resistance (Rainbolt & Dusky, 2007). The commercial products using by producers in the EAA are Dupont K-4 (%hexazinone + diuron), Prowl 3.3 (%pendimethalin), Envoke (%trifloxsulfuron).

Other tool as like flooded conditions can keep sugarcane field without high infestations because the anaerobic environment impair seedlings germination and in the EAA water tables can be manage to support weed control.

### 3.7-Diseases and pests control

In the EAA, yield loss assessment due to diseases is for Sugarcane Rust (Raid & Comstock, 2006), Sugarcane Mosaic Virus (SCMV), Sugarcane Leaf Scald Disease, Pineapple Disease (Raid, 2009), Eyespot Disease (Comstock & Gilbert, 2009) and Sugarcane Ratoon Stunting Disease (RSD) but these are not great problem to producers and efforts have been done to increase varietal susceptibility and improve resistance in the varieties planted. The use of resistant cultivars is often the easiest, most economical method for controlling plant diseases.

Florida sugarcane is attacked for several insects, the mains insects that promote loss yield are: sugarcane borer (*Diatraea saccharali*), lesser cornstalk borer (*Elasmopalpus lignosellus*), white grubs (*Ligyrus subtropicus*) and wireworms (*Melanotus communis*). To apply pest management fields should be scouted every 2 or 3 weeks. Flooded conditions avoid some pests as such white grubs and wireworms (Cherry & Nuessly, 2008).

### 3.8-Operations Schedule

Sugarcane cultivation requires mechanical operations during some months in the year, the mains operations are: planting, fertilizers and chemical products applications, harvest and crop rotation when it is done.

Considering this the operations for EAA, there are:

1. Planting: begin late August to January and is included soil preparing to receive sugarcane seed pieces.
2. Fertilizers: amounts of fertilizers are applied in the furrow with seed piece planting or upon harvest on the successive ratoons.

3. Herbicides: applies can vary on each field, some growers applies herbicides before weed emerge (pre-emerge), others after weed emerge (after-emerge), but generally is applied in few weeks before and after sugarcane planting, after each harvest also to avoid competition between weeds and sugarcane plant, so the period is the same to planting and harvest.

4. Ripeners: the period to apply ripeners usually is some weeks before harvest when the farmers do not have natural conditions for sugarcane maturation. In the EAA the undesirable conditions occurs in the fall begin, when the weather still with high temperatures and water.

5. Harvest: in the EAA begin in October and finish in mid-April.

6. Crop rotation: during the year when crop rotation is done, it is planting in the spring begin and plow down in the end of summer or begin of fall.

Table 9 Operations schedule for sugarcane cultivation in the EAA fields

<table>
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<tr>
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<th>Jan</th>
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<th>Sep</th>
<th>Oct</th>
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<th>Dec</th>
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</thead>
<tbody>
<tr>
<td>Planting</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
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<tr>
<td>Fertilizers</td>
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<td>Herbicides</td>
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<tr>
<td>Ripeners</td>
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<tr>
<td>Harvest</td>
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<tr>
<td>Crop rotation</td>
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</tbody>
</table>

In the sugarcane cultivation schedule is not included applications for diseases or pests because is not required since it occurs, but if some disease or pest should be controlled, usually are fast application on undetermined time.

With all the operations steps, since preparing the backyard till sugarcane process at mill is possible know the challenge to water management in the EAA and solutions to implant a system sustainable.

3.9-Water management

Florida sugarcane growers irrigate and drain their fields by subirrigation and open ditch drainage. Subirrigation is defined as supplying water to the crop root zones by
controlling the water table. A water table is established above an existing water table or above a restrictive (impermeable) soil layer by pumping water into open ditches.

Drainage involves reversing the process. The ditch water levels are lowered allowing water to flow out of the soil profile back into the ditches. The effectiveness and efficiency of this type of system can vary widely depending upon site-specific conditions. South Florida lends itself to water table management because of its flat land, relatively high soil hydraulic conductivity underlain by a restrictive layer, and large quantities of available water (Lang et al, 2002).

Sugarcane production generally involves large farm sizes, due in part to the high cost of irrigation and drainage. Each individual grower must have both a surface water management permit and a consumptive use permit. The permits must be processed by the South Florida Water Management District and the Florida Department of Environmental Regulation.

3.9.1-Water tables

Water table underground levels deeper than 24 inches (60 cm) are usually maintained for sugarcane. At times, the water table is allowed to fall to 30 to 36 inches (75 to 90 cm) to enhance sugarcane growth and sugar quality. This practice is prevalent primarily in areas where the soil is raw, fibrous peat that holds excessive water in the plant root zone under conventional water table management. A seven year study at the EREC showed that 30 inches to the water table was optimum for sugarcane on the basis of tonnage per acre.

Production dropped only 5% with a 15 inches (37 cm) water table depth (Lang et al, 2002). It should be noted that these studies were conducted under precise water table control in lysimeters where the normal hazards of inundation following heavy rains was not a factor. It has been suggested that the target water table level for sugarcane be between 23 and 30 inches (57 and 75 cm).

Studies have shown both plant and ratoon sugarcane crops produced high yields at an average water table of 22 inches (55 cm). Water tables varied during the study from a field average low of 39 inches (97 cm) to a high of surface ponding. The variation in water table level around the average illustrates the problem with managing farm water using annual average water table values.

3.9.2-Sugarcane under flooding conditions

Sugarcane can be cultivated under flooded conditions during few weeks without affect the yield, that happens because exist varieties enables to growth, exchange nutrients and gases under flooded conditions. According with Glaz and Morris (2006), the sugarcane physiological and morphological characteristics have flood tolerance and transpiration and stomatal conductance is not affected by flooding.
During experimental test, 40 varieties have been tested in Florida and all genotypes have aerenchyma in the roots and after being flooded, all varieties had formed aerenchyma in the stalk (Van Der Heyden et al, 1998). The aerenchyma size can differ between varieties and can appear or be modified after flood conditions, some varieties have more ability to develop under flood conditions because have already a good size of aerenchyma before flood conditions.

B. Glaz and D. Morris had tested CP 89-2143 and CP 88-1762 with two water tables deep, 8 and 18 inches (20 and 45 cm), with constant and repeated flood durations of 7-14 days. The both varieties were tested during plant-cane, first-ratoon and second-ratoon, then cane and sucrose yields were compared, and also the aerenchyma size was related.

The sugarcane cultivar CP 89-2143, present around 31% of EAA, had lower cane and sucrose yields, but was the least affected by water table depth treatments. Further, CP 89-2143 had a larger stalk aerenchyma than CP 88-1762, that appears in around 20% of sugarcane fields. Although CP 88-1762 had a smaller aerenchyma it had a better cane and sucrose yields than CP 89-2143 under flooded conditions. The best productivity of CP 89-2143 was under 18 inches (45 cm) water table depth, constant or periodic flooding.

Basically, the study can conclude that sugarcane growers should consider constantly shallow water tables, near 8 inches (20 cm), are more detrimental than periodic flooding with flood durations of up to 14 days. Further, research supports sugarcane growers to develop enhanced strategies to sustain yields under these conditions.

Although sugarcane yields high water tables is a challenge in the EAA, some benefits have supported by scientist, as such:

- To keep the soil under anaerobic conditions to impede microbial oxidation (Morris et al., 2004)
- To prevent larva development such as White Grub or “root weevil” (Glaz & Cherry, 2003)
- To avert weed growth and reduce herbicides use (Rainbolt & Dusky, 2007).
- To keep soil organic matter moist enough to prevent it from burning during pre-harvest burning operations (Glaz, 2007)
- To protect sugarcane from freeze during the cold month of the year because water forms a protective layer on the plant by trapping air between the plant and the ice (Glaz, 2007).

The height water tables for sugarcane cultivation have been studying in the USDA Belle Glade Experiment Station. The researches aim to support strategies to modify sugarcane production system, turning the production sustainable. If sugarcane can develop under short period flooded, the water management can create ways to store water in the field to avoid environmental issues.
4-New Farming System Proposal

The traditional sugarcane cultivation practices in the EAA in the present moment have several implications that affect the ecosystem, as drainage that supports the runoff from field, bring the nutrients to water and giving rise to contamination on lakes and estuaries. During crop development, water consumption for irrigation also contributes to lack water from Lake Okeechobee.

In the past, water from Lake Okeechobee flowed naturally through to southeast of Florida state. The lake served as a natural storage mechanism that adjusted downstream flows by storing water in wet years and gradually releasing water during dry periods, as a 30-mile wide sheet-flow of water southward through the Everglades and to Florida Bay (Clarke & Dalrymple, 2003). However, the manipulations of water systems in south Florida have created hundreds of miles of canals, dams, and other diversions. These efforts significantly altered the region’s hydrology and introduced unanticipated changes into the ecosystem (see Figure 10). Presently, efforts by The Comprehensive Everglades Restoration Plan (CERP) established strategic goals such as “get the water right”; restore, preserve, and protect natural habitats and species; and foster compatibility of the built and natural systems (SFERTF, 2000).

![Figure 12. Historic and Current flow of Lake Okeechobee.](image)

However, the water issues are not the unique problem to sugarcane cultivation nowadays, the currently drainage applied in the lands, keeping the soil exposed to oxygen, accelerate organic matter oxidation, occasioning soil subsidence in the Histosols. Further soil loss, the soil subsidence contributes to greenhouse gas emissions.
Another step that should be discussed is burn sugarcane before harvest, because the burned also discharge greenhouse gases and declines the organic matter in the soil supercies.

Thus, the aim to create a new farming system is mitigated the environmental issues and preserve the ecosystem, keeping the sustainable on sugarcane cultivation.

The ecosystem restoration includes a new farming model to store water in the wet season, including months from June to October, keeping sugarcane under flooding conditions, thus environmental benefits will be create and some challenges with sugarcane cultivation must be confronted.

The proposal for the new system is support with initial experiments develops by USDA, UF/IFAS, Department of Energy, but far more researches is needed. However, challenges is redesign the periods for planting, harvest and all others operations to keep the field available for water storage.

4.1- Operations schedule for a New System

A modified schedule operations, different from table 7, should studied to implement on farms. The new schedule displayed below, shows the basically modifications on period of sugarcane operations to get free the time for water storage.

<table>
<thead>
<tr>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
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<th>May</th>
<th>Jun</th>
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<td>1</td>
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<td>2</td>
</tr>
</tbody>
</table>

Table 10 Operations schedule for sugarcane cultivation with water storage

The modifications require attention for how sugarcane wills growth under that conditions and whether problems with nutrition, pests or diseases will show up. Thus, researches with this new farming system model should start in the EAA.

4.2-Water storage diagrams
The options for producers store water is based in two models. The first one is rotational storage with three fields (Field A, B and C). In this case, which subdivided sugarcane field will store water per one week, and after pumped forward to other field (see Figure 11). The second model is flow-way storage, where the water will stay one week on each field and pumped forward (see Figure 12).

4.2.1- Rotational Storage

Figure 13. Rotational Storage Model

4.2.2-Pulsed Flow-way Storage

Figure 14. Pulsed Flow-way Storage Model
4.3- Varieties management

To implement a new sugarcane farming system in the EAA is important to know the characteristics about the mainly varieties planted in this region nowadays thus, the producers can change the period for sugarcane crop operations, as such planting and harvest. Further, producers can chose varieties able to develop itself under flood conditions and uptake greater amounts of phosphorus from soil, avoiding nutrient leaching. To supply the both desirable characteristics varieties should be investigated to turn available sugarcane crop development more sustainable in the EAA.

Water tables management can vary widely, different deeps and durations affect cane and sugar yield in each variety. So experiments are required, mainly with varieties already planted in the EAA to recommend growers how should be the water management.

Phosphorus accumulation in sugarcane plant also can differ with varieties, the sugarcane stalk is the primary plant part that is harvested and carried to the factory, however to develop cultivars with stalks that accumulate increased amounts of P, it would be more practical to measure phosphorus quantities with sample of leaves rather than stalks (Glaz et al, 2004). Consciously, the producers can chose varieties with higher phosphorus accumulation.

The six varieties most planted are CP 80-1743, CP 89-2143, CP 88-1762, CP 78-1628, CP 72-2086 and CP 84-1198, in decreased order. All the varieties should be investigated to turn available sugarcane crop development in a new system, with water storage between June and October. The mainly varieties characteristics required for a new system are exposed on Table 11, the information was retrieved from researches of USDA and University of Florida.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Harvest Season</th>
<th>Cold Tolerance</th>
<th>Frost Tolerance</th>
<th>Soil preference</th>
<th>P leaf tissue concentration mg.kg⁻¹</th>
<th>Water tolerance</th>
<th>Sugar per ton</th>
<th>Yield (T/ac)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CP 89-2143</td>
<td>early/middle/late</td>
<td>medium to good</td>
<td>good</td>
<td>Organic</td>
<td>—</td>
<td>medium</td>
<td>high</td>
<td>medium</td>
</tr>
<tr>
<td>CP 88-1752</td>
<td>early</td>
<td>poor</td>
<td>medium</td>
<td>Organic</td>
<td>1.42</td>
<td>poor at planting</td>
<td>medium</td>
<td>high</td>
</tr>
<tr>
<td>CP 80-1743</td>
<td>early</td>
<td>poor</td>
<td>good</td>
<td>Organic</td>
<td>1.27</td>
<td>poor at planting</td>
<td>high</td>
<td>medium</td>
</tr>
<tr>
<td>CP 78-1629</td>
<td>middle</td>
<td>poor to good</td>
<td>good</td>
<td>Sand/Organic</td>
<td>1.12</td>
<td>high</td>
<td>medium</td>
<td>medium</td>
</tr>
<tr>
<td>CP 72-2086</td>
<td>late</td>
<td>good</td>
<td>good</td>
<td>Sand/Organic</td>
<td>1.37</td>
<td>poor at planting</td>
<td>medium</td>
<td>medium</td>
</tr>
<tr>
<td>CP 84-1198</td>
<td>middle</td>
<td>medium</td>
<td>medium</td>
<td>Organic</td>
<td>1.25</td>
<td>medium</td>
<td>medium</td>
<td>high</td>
</tr>
</tbody>
</table>

The sugarcane varieties should cooperate for farms work runs according the new schedule of sugarcane cultivation. A strategic plan can be done with knowledge of currently or new varieties planted in the EAA. But a perfect combination of varieties for a
new system is unknown yet, for now the table contains an abstract of characteristics that can be useful to know which variety is adaptable or not.

At planting, varieties as such CP 88-1762, CP 80-1743 and CP 72-2086 do not support flood conditions, otherwise the others can tolerate, keeping the stand of plants in the field.

During the harvest, varieties as such CP 89-2143, CP 78-1628, CP 72-2086 and CP 84-1198 have preference for a new system, because are adapted to harvest in the middle and late season.

Characteristics like as cold and frost tolerance is important to producers know in a shorter harvest season as is proposed, thus, in case of cold forecast producers can make a right decision harvesting the poor tolerance variety first.

Phosphorus uptake is also a preferential characteristic for a sustainable farming system, CP 88-1762 and 72-2086, nowadays are varieties planted that most absorb phosphorus (Glaz et al, 2004).

As a sustainable system sugar content and cane yield are not the head characteristics that should be reaching, however a combination between an average yield and varieties able to grow in the new system should be chosen.

5-Discussions

The proposal for a new system aims at supporting the preservation of the ecosystem in the modified EAA sugarcane cultivation. This shift results in several benefits for the environment. On the other hand, have many challenges to deploy this system in crop cultivation traditionally an already established as the sugarcane.

To store water in the sugarcane fields during the period of the rainy season from June to October, the farms should be redesigned cooperating to manage water. Becoming more sustainable farms will avoid the need for land purchases by the government for preservation of the environment.

This new system should be encouraged by the government, which subsidized the water storage by producers and besides that research organizations should continue researches and extension to help producers implement sugarcane farms under flood conditions.

The main researches objectives in the EAA to implement the new system should be:

- Search for varieties resistant to floods;
• Varieties that absorb great amounts of phosphorus from soil without the need of application of phosphate fertilizer;

• Definition of height water tables for each variety holding a medium yield in sugar content and cane stalks;

• Projects to redesign the farms making them enabled for storing water.

6-References


Sugarcane Horticulture and Management in the EAA


