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Possibilities for growing kenaf (*Hibiscus cannabinus* L.) in Argentina as biomass feedstock under dry-subhumid and semiarid climate conditions

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ABSTRACT

Kenaf (*Hibiscus cannabinus* L.) is an annual herbaceous crop with a high biomass production.

In this paper, and based on international bibliography, the authors outline an agroclimatic and agro-ecological zoning model to determine potential growing areas in Argentina for kenaf. The bioclimatic variables considered were: 150 frost-free days, isohyets of 500, 780 and 1200 mm corresponding to November–March (the growing period), a mean annual temperature of 11.5 °C and temperatures of 15 °C, 20 °C, 25 °C and 27 °C during the growing period.

The agroclimatic indices, which determine different classes of suitability, were integrated in a Geographic Information System in order to create thermic and hydric regions. The maps were superimposed, and the overlapping regions delineated the agroclimatic zoning.

Thornthwaite's Moisture Index = 0 was overlapped on the agroclimatic zoning map to guarantee that the lands to be occupied by the proposed energy crop would be located under dry-subhumid, semiarid or arid climate conditions. This last map was superimposed on another one that determined unsuitable soils for traditional agriculture. The overlapping regions defined the agro-ecological zoning for kenaf.

This is an innovative work, made by the implementation of a geographic information system that can be updated by the further incorporation of complementary information, with the consequent improvement of the original database. Furthermore, its focus is not merely local since the model described may be applied to any part of the world, using the agroclimatic limits presented in this paper.

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1. Introduction

Economic and population growth, together with industrialization processes, have led to an increase in energy consumption and demand. The non-renewable sources of energy in the planet are finite and are depleting at a fast rate. In today's society, researchers around the world are searching for ways to develop alternative fuel sources.

A very promising renewable energy source is biomass, which can be used to produce biofuels. However, exploitation of biomass for biofuels is restricted due to the competition of biomass as food/feed or fodder resource. Only non-edible crops have a clear opportunity as a source of biofuels, either as sole block plantations or accompanying food crops.

Furthermore, there is a rising interest in the world for non timber-yielding vegetable species as suppliers of cellulosic fiber. This would defuse potential threats for the paper industry, since bio-refineries and the production of bio-fuels could reduce the availability and increase the price of raw material for this industry in the future [1].

In addition, the negative effects of climate change are clearly observed in the modifications of normal weather cycles. Rainfall dependent agro-ecosystems are increasingly experiencing higher uncertainties in agricultural production.

One of the crops that could surmount the problems mentioned above is kenaf. The productive versatility and agronomical rusticity of kenaf make it a promising species for Argentina. The crop fulfills many purposes and its biomass can be used both in the paper industry (paper pulp) and as an energy source, through thermo chemical processes (gasification) or production of briquettes.

1.1. General characteristics

Hibiscus cannabinus L. (Malvaceae) is an annual plant native to Africa that can grow in a wide range of climates and types of soils [2]. This species has several common names: kenaf, bimli, bimlipatum jute, deccan hemp. It is an erect, herbaceous, single stemmed plant and it can reach heights of up to 1–5 m. The plant has been cultivated for more than 4000 years and it is rich in fibers, with a high production of lignocellulosic material.

Kenaf is fast growing and, in barely 4 months, it can reach heights of 3 m, although 6 m-high plants have also been found. For this reason, in tropical and sub-tropical areas, it is possible to obtain up to 2 harvests per year.

1.2. Uses of kenaf

Kenaf is mainly grown as a fiber crop, but it is also well known as a biomass crop [3] and for the phyto-remediation of soils [4]. It presents several advantages over other wooden fibers, since the process of transforming the pulp into paper requires less energy and fewer chemicals [5].

When the crop is destined for fiber production, the cultivars must be close to a transformation facility or industry. The fibers, often compared with the ones obtained from hemp (*Cannabis sativa*) or jute (*Corchorus capsularis*), have many applications. They are traditionally used in the manufacture of ropes, bags, cordages, and carpet yarns. In addition, they can also be employed as pulp fiber and for animal grazing. However, they also have many innovative uses, such as the manufacture of paper, wooden products, mats, and absorbent material for oils and liquids. They can also be employed in construction work and in the production of automobile bodies [6].

The paper obtained from kenaf fibers is whiter, more resistant and yields improved results upon printing. For these reasons, the fibers are also employed in the manufacture of recycled paper. They contain less lignin than traditional wooden pulp and this reduces the energetic costs involved in the production process [7,8].

The seed contains between 18 and 35% of semi-dry edible oil [9], a percentage similar to *Arachis hypogaea* (peanut) oil (10). The oil can be used to manufacture soaps, in cosmetic products and in lubricants, linoleum, paints and varnishes. It can also be employed in the production of biofuels and high-value compounds [11].

Several studies have shown that kenaf is a crop with forage potential [12]. The leaves and stalks are appropriate for the diets of ruminants because of their protein content. The leaves alone have 21–34% protein content, while the stalks are in the 10–12% range and the whole plant has levels of 16–23% [12]. This species has successfully replaced the dehydrated alfalfa that is used for feeding sheep [13] and it has also been stored in silages for young bulls and lambs [14]. The equipment to harvest forage for silage has to be modified minimally [15].

In addition, young plants can be used as fodder and young leaves as vegetable. The dried stems can be used as fuel [16].

1.3. Productivity

Kenaf can enter into crop rotation cycle as a spring-summer crop. There are many varieties with 60, 90, 120, 150 and 180-day cycles. The length of the growing period becomes crucial if the aim is to obtain biomass.

Kenaf was sowed for the first time in a commercial scale in Argentina in 1995. After the harvest, the material had to be taken to a commercial plant to be turned into pulp and, later, mixed with the bagasse pulp to make paper. Unfortunately, the early summer of 1996 was one of the driest registered in the northeast of Argentina and, at the time, the idea of planting it for commercial purposes was abandoned. In Argentina, yields of more than 17.5 ton/ha of DM have been reached [17]. However, the yields of each independent assay were extremely variable, fluctuating between 4.3 and 13.3 ton/ha, depending on the location and the weather. Furthermore, it was observed that cultivars had similar yields in each particular location tested, indicating that this factor exerts a significant influence and has to be specifically considered when the crop is used for commercial production.

According to [16] total production of green plants may be around 36 ton/ha, yields of fodder from 10 to 14 ton/ha and fiber yields from 1 to 6 ton/ha. Annual seed yields may be about 350–400 kg/ha.

The recollection of stalks presents difficulties because the fibers are hard and have high humidity levels. For instance, in Italy, harvesting is done in winter employing a foliage chopper and using the dry material obtained after the frosts. In Spain,