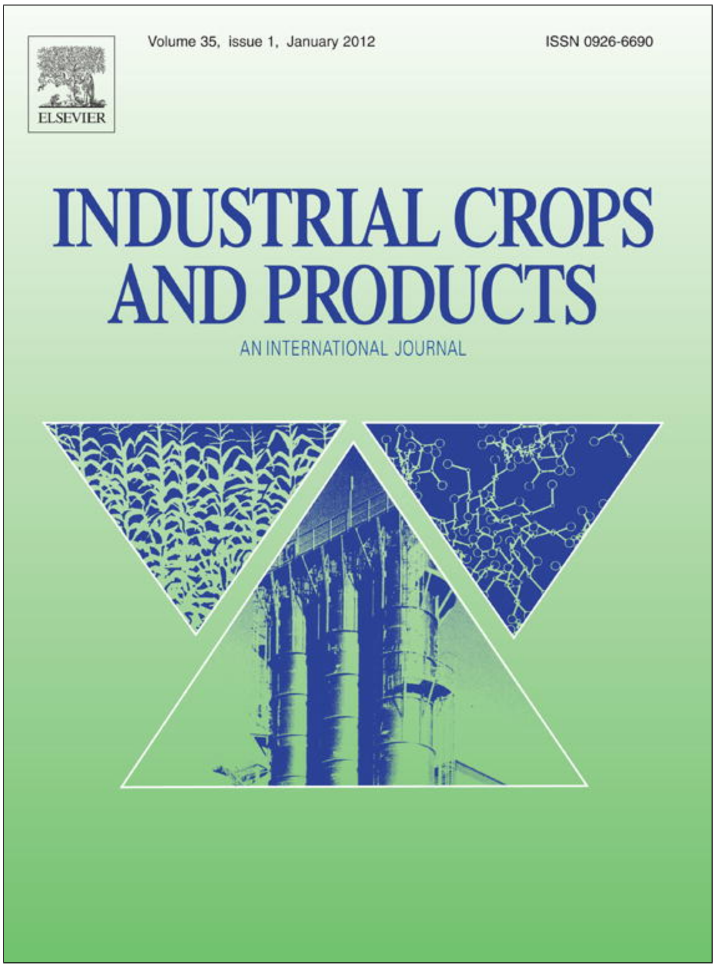

Industrial Crops and Products 40 (2012) 185–191

Contents lists available at SciVerse ScienceDirect

Industrial Crops and Products

journal homepage: www.elsevier.com/locate/indcrop

Developing an agro-climatic zoning model to determine potential production areas for castor bean (*Ricinus communis* L.)

Silvia L. Falasca[a,*], Ana C. Ulberich[b], Eliana Ulberich[c]

[a] *Researcher of Argentine, National Research Council, Climate and Water Institute, INTA, Las Cabañas y Los Reseros S/N, Castelar, Buenos Aires, Argentina*
[b] *CINEA (Environmental Studies and Research Centre), Facultad de Humanas (School of Humanities), Universidad del Centro de la Provincia de Buenos Aires, Pinto 399, Tandil, Argentina*
[c] *English Teacher Training School, Instituto Superior San José, Tandil, Argentina*

ARTICLE INFO

Article history:
Received 8 December 2011
Received in revised form 25 February 2012
Accepted 27 February 2012

Keywords:
Agroclimatic aptitude
Argentina
Castor bean
Bioclimatic requirements
Sub-humid to semiarid regime

ABSTRACT

The aim of the present paper was to define the agroclimatological aptitude of the Argentinean semiarid and arid zones to produce industrial oil and biofuel from castor. Castor bean oil (*Ricinus communis* L.), which currently has more than 700 applications, has an “unlimited” market because its uses are multiple and there is a growing international demand. In Argentina its production was always relegated to marginal soils, but since it ceased to be grown in 1989 castor oil is imported. Due to the international prices of castor bean oil, its multiple applications and in Argentina its diverse climate, this work on potential cultivation areas considering the species bioclimatic needs was carried out. To define the agroclimatic aptitude of this crop in Argentina, the climatic data of the meteorological stations corresponding to the period 1981–2010 was analyzed. Using available databases and geographical limits for the different variables, aptitude types were defined and mapped: optimal (>750 mm; temperature 24.0–27.0 °C; >−8 °C; >180 frost-free days); very suitable (>750 mm; temperature 21.0–23.9 °C; >−8 °C; >180 frost-free days); suitable with humid regime (>750 mm; temperature 16.0–20.9 °C; >−8 °C; >180 frost-free days), suitable 1 with sub-humid regime (450–750 mm; temperature 24.0–27.0 °C; >−8 °C; >180 frost-free days); suitable 2 with sub-humid regime (450–750 mm; temperature 21.0–23.9 °C; >−8 °C; >180 frost-free days); suitable 3 with sub-humid regime (450–750 mm; temperature 16.0–20.9 °C; >−8 °C; >180 frost-free days); marginal due to humidity (200–450 mm); marginal due to temperature (<16.0 °C); marginal due to frosts (<180 frost-free days or <−8 °C) and not suitable areas (combination of 2 or more of the following variables: <200 mm; <16.0 °C; <−8.0 °C; <180 frost free days). Areas classified as optimal and very suitable in the eastern sector of Argentina overlay with the areas for the production of traditional oilseed crops. So, its cultivation is not recommended. The areas that can be destined to its cultivation are the ones zoned as suitable, defined under conditions of sub-humid regime (450–750 mm), with different thermal regimes: suitable 1 (24.0–27.0 °C), suitable 2 (21.0–23.9 °C) and suitable 3 (16.0–20.9 °C). Therefore, land might be used in parts of the provinces of Salta, Jujuy, Tucumán, Chaco, Formosa, Santiago del Estero, Córdoba, San Luis, La Pampa, western Buenos Aires, La Rioja and Catamarca. This agro-climatic zoning model to determine potential production areas for castor bean can be applied to any part of the world, using the bioclimatic limits of the species presented in this work.

1. Introduction

Ricinus communis L. is known by several names including: ricino, castor, tártago, higuerilla, mamoneira, mamona, palma christi, higuereta, castorbean, castor-oil plant.

It is a member of Euforbiaceae family which is originated from tropical countries.

This stout, robust shrub-like plant with reddish to purple stems may reach 4–5 m in height. The large (10–76 cm), umbrella-like leaves have 5–9 pointed, finger like lobes. Long purple leaf-stems are attached near the centers of the leaf blades.

Greenish-white or reddish-brown flowers are produced in narrow, upright clusters. The fruit is a three-lobed, green or red capsule with a soft, spiny exterior. One large, mottled, attractive seed develops in each lobe. The flowers are male and female on the same plant, and are produced on a clustered, oblong, terminal spike (Reed, 1976).

The seeds of the different cultivars differ in size and in external markings but average seeds are of an oval, laterally compressed

---

[*] Corresponding author. Tel.: +54 11 4621 0125/1684/1463/5663/8496.
E-mail addresses: slfalasca@gmail.com, sfalasca@conicet.gov.ar (S.L. Falasca), ulberich@fch.unicen.edu.ar (A.C. Ulberich), eulberich@gmail.com (E. Ulberich).

0926-6690/$ – see front matter © 2012 Elsevier B.V. All rights reserved.
doi:10.1016/j.indcrop.2012.02.044

form. The smaller, annual varieties yield small seed- the tree-shaped types form large seeds. They have a shining, marble-gray and brown, thick, leathery outer coat, within which is a thin, dark-colored, brittle coat. A large, distinct, leafy embryo lies in the middle of a dense, oily tissue (endosperm).

It is a plant with C3 photosynthetic metabolism, which under high temperature conditions and relative humidity presents high photosynthetic rates but under low relative humidity conditions it is reduced drastically as a consequence of the stomatal closure (Dai et al., 1992).

It is believed that castor bean originated in Africa, Abyssinia, current Ethiopia from where it spread to the Middle East as a wild plant. In India and China, it was known 3000 years ago. More than 400 years ago, the Egyptians used the oil for lighting their houses; it seems to have been a highly valued plant because its seeds have been found in some of their tombs. It was introduced in the American Continent by the Portuguese colonizers who traded slaves to Brazil in their galleys (Beltrão, 2005).

Global castor seed production is around 1 million t/year. Leading producing areas are India, China, Brazil and the former USSR; where there are several active breeding programs for castor.

The Argentine energy matrix is based on petroleum and natural gas derivatives, resources with local reserves in decrease, raising the possibility of the country acting as purely importer in the short term. The fuel that is used the most is “diesel”, which is currently blended with a 7% biodiesel, 95% of it coming from soybean (*Glycine max* L. Merr.).

In Argentina, castor bean production was historically marginal and after it ceased to be cultivated in 1989 Argentina became importer. In the provinces of Misiones and Salta trials have been done to determine which castor bean cultivar adapts to the local environmental conditions and oil is being produced (Falasca and Ulberich, 2006).

In 2006, in Misiones there was an entrepreneurship and 3000 ha were planted; a yield of 3400 kg of seeds per hectare was produced with an oil performance of 45% on a dry basis. However, the venture failed because of a false promise to buy all the production of the farmers. Since 2009, there have been new entrepreneurships.

The return of the crop to Argentina would allow the substitution of the imports; and if it is widespread, our country could become exporter of castor bean oil.

1.1. Uses

Castor seed contains between 40% and 60% oil, which is rich in triglycerides, mainly ricinolein. This oil is highly viscous, its coloration ranges from a pale yellow to colorless, it has a soft and faint odor and a highly unpleasant taste.

Castor oil dissolves easily in alcohol, ether, glacial acetic acid, chloroform, carbon sulfide, and benzene. It is made up of the following fatty acids 91–95% ricinoleic acid, 4–5% linoleic acid, and 1–2% palmitic and stearic acids (Beltrão, 2005).

The castor biodiesel has very interesting properties (very low cloud and pour points) that show that this fuel is very suitable for using in extreme winter temperatures (Beltrão, 2005).

The castor bean oil contains 1–5% of a cytotoxic protein, named ricin, one of the most potent and deadly plant toxins known (Aslani et al., 2007). The oil extracted from the castor bean already has a growing international market, assured by more than 700 uses, ranging from medicines and cosmetics to substituting petroleum in the manufacturing of biodiesel, plastics and lubricants (Azevedo et al., 1997; Freire, 2001).

Castor oil and its derivative castor biodiesel is indispensable for preventing fuels and lubricants utilized in aircraft and space rockets from freezing at extremely low temperatures. Raw castor oils' major market is beginning to open in the energy field, with the growth of biodiesel.

Each hectare of castor oil bean plants planted in arid and semi arid regions produces 350–650 kg of oil, which in turn produces 280–520 kg of biodiesel per hectare.

Besides, castorbean leaves can serve as food for silkworms; the pulp for paper manufacture; the cake, coming after pressing the seeds, is used as organic compost possessing too, nematicidal effect; cultural waste can return 20 t/ha of biomass to the soil (Silva et al., 2008).

1.2. Climatic requirements

According to Duke (1983), castor bean is present in different life zones: from cool temperate moist forest to cool temperate wet forest through tropical desert to wet forest, and it is reported to tolerate annual precipitation of 200–4290 mm and annual temperature of 7.0–27.8 °C.

In Argentina, castor bean is cultivated as an annual plant, but in tropical and subtropical regions it is perennial. In environments with severe frosts or with a very marked dry season it is also dealt with as an annual crop to avoid death of plantation.

In our country, it grows spontaneously as weed up to 40°S latitude. In the Buenos Aires Province, it can even be seen growing by the streams, also in the margins of the highly contaminated, within the Matanza-Riachuelo basin.

The castor plant is easy to grow and is tolerant to drought, which makes it an ideal crop for the extensive semi-arid regions globally (EMBRAPA, 2006).

The term ‘frost-free season’ is generally used to designate the number of days without killing frost in any region. It is determined strictly by the prevailing temperature conditions, and only expresses what may be called the ‘thermal growing season’ of a large area. These may prevent a specific crop from being grown in an area, even where the season is satisfactorily frost-free (Thran and Broekhuizen, 1965).

At least a 140 day growing season is required to produce satisfactory yields of castor seed, and a 140–160 frost free day season is more desirable. However, in arid and semi arid regions the actual growing season to first harvest must be increased to 180 days (Amorim Neto et al., 1999).

The seed may fail to set, however, if the temperature stays above 30 °C for an extended period, 15 °C being the base temperature for germination (Amorim Neto et al., 2001).

It can resist long periods of drought, even during fruit maturation. However, it produces lighter seeds with a lower percentage of oil (EMBRAPA, 2007).

The temperature must oscillate from 20 to 35 °C to make certain there are productions of high commercial value, with an optimum temperature of around 24–27 °C. Short low intensity frosts are tolerated although they can lower its yield (Amorim Neto et al., 2001).

The EMBRAPA (2007), considers that the economic crop is only viable when the annual rainfall regime totalizes 400–500 mm.

The ideal precipitation range for a good yield varies between 750 and 1500 mm, with a minimum of 600–750 mm during the whole crop cycle, so that the plant gets 400–500 mm until the beginning of flowering (Távora, 1982).

In regions with rainfall totals below 500 mm in the rainy season, castor bean loses much of its economic production, increasing risks of total loss of harvest or very poor performance (Amorim Neto et al., 2001).

Research carried out in Brazil, showed that for the Nordestina (Brs-149) cultivar as well as for the Paraguaçu (BRs-188), the average productivity potential varies from 1500 kg ha^{-1} in semiarid conditions to 5000 kg ha^{-1} in irrigated conditions (Carvalho, 1988).

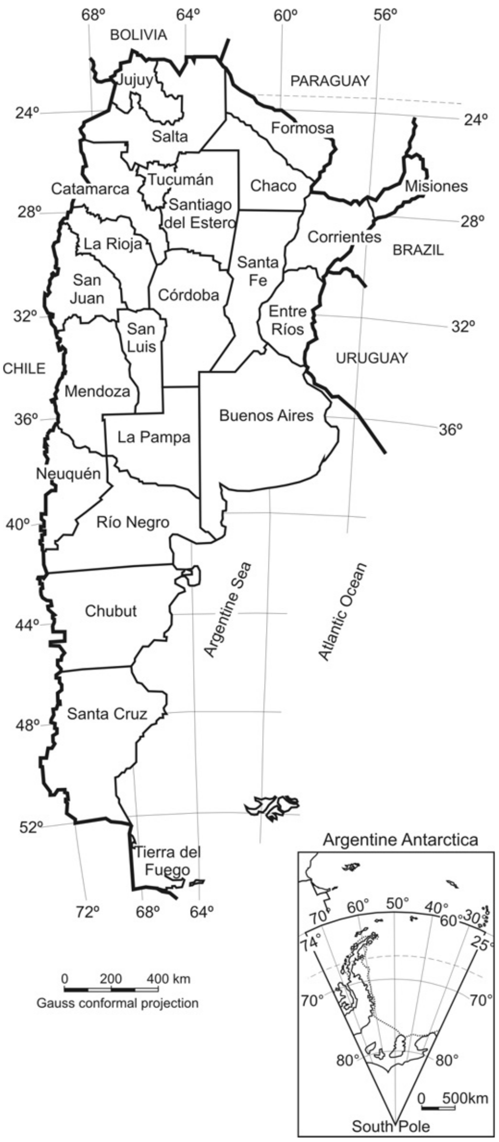

Fig. 1. Argentina's political map.

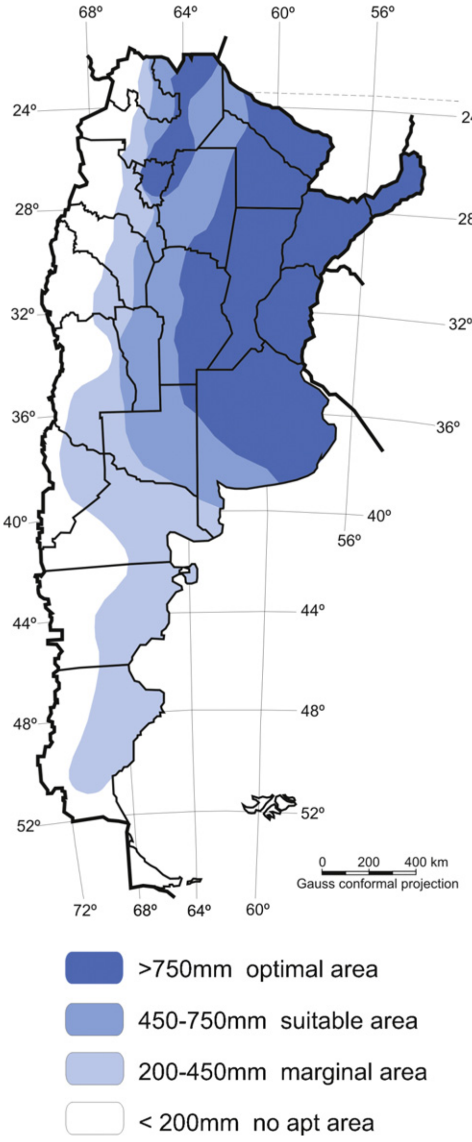

Fig. 2. Annual precipitation.

That means that when the plants do not suffer hydric stress they are efficient in the use of water (Barros Junior et al., 2008).

Temperatures above 40 °C cause flower abortion, sex reversal of flowers from female to male and performance reduction with the consequent decrease in oil production. Temperatures below 10 °C produce fewer seeds due to a loss vitality of the pollen (Beltrão and Silva, 1999).

The fact that it is possible to find individuals from 250 mm annual precipitation to above 4250 mm indicates the extraordinary adaptation capacity of the species.

The castor is considered a plant of long days, although it adapts well in regions with short photoperiods, which must not be shorter than 9 h, it best develops in areas with good exposure to solar radiation, with at least 12 h of sun a day (Beltrão and Silva, 1999; Kumar et al., 1997). Long days (>12 h) favor the formation of female flowers and short ones male (Mendoza and Reyes, 1985).

The soils of its natural habitat have good drainage. It develops well within the 4.5–8.3 pH range (Reed, 1976).

Thus, the castor is a species that can develop easily with wide ranges of temperature, precipitation and altitude, which turns it into an aggressive colonizing species that can become weed.

The aim of the present paper was to define the agroclimatological aptitude of the Argentinean semiarid and arid zones to produce industrial oil and biofuel from castor.

2. Materials and method

To define temperature and rainfall zones and frost free days, mean annual precipitation and temperature records (for the period 1980–2010) from all meteorological and agrometeorological stations available in Argentina were used. Based on international bibliography, the agro-climatic zones were defined as specific combinations of rainfall, frost free season and temperature zones.

As thermal limit the average annual temperature of 15 °C was used as it represents the base temperature for growth; lower temperatures determine agroclimatic marginality. From the thermal point of view, the 16.0–20.0 °C range represents a suitable area, the 21.0–23.9 °C a very suitable area and the 24.0–27.0 °C range an optimal area (Amorim Neto et al., 2001).

According to Amorim Neto et al. (1999), in arid and semi arid regions the growing season must be increased to 180 days, although in humid climates castor is cultivated with only a 100 frost-free days. Analyzing frost free days, the area with 180 was considered

Table 1
Examples of some meteorological stations according to agroclimatic types.

Agroclimatic aptitude	Meteorological station	Lat. S	Long. W	Alt. m	Mean temp. October–February	Rainfall mm	Frost free days	Mean Minimum annual temperature
Optimal	OBERÁ	27°29′	55°08′	343.0	26.2 °C	1973.0	362	−1.2 °C
Very suitable	CONCORDIA	31°18′	58°01′	38.0	22.9 °C	1354.0	356	−2.0 °C
Very suitable with irrigation	SAN JUAN	31°34′	68°25′	598	22.7 °C	92.4	263	−4.5 °C
Suitable with humid regime	PEHUAJÓ	35°52′	61°54′	87.0	20.0 °C	1015.0	238	−6.3 °C
Suitable with subhumid regime 1	SANTIAGO DEL ESTERO	27°46′	64°18′	199.0	25.3 °C	603.0	314	−2.9 °C
Suitable with subhumid regime 2	VILLA REYNOLDS	33°44′	65°23′	486.0	22.0 °C	534.0	240	−6.2 °C
Suitable with subhumid regime 3	SANTA ROSA	36° 34′	62° 37′	191.0	20.0 °C	635.0	201	−7.8 °C
Suitable with complementary irrigation	ASCASUBI INTA	39°23′	62°37′	22.0	19.7 °C	450.0	221	−6.3 °C
Marginal (frost)	COLONIA EMILIO MITRE	36°42′	63°45′	313.0	18.9 °C	517.0	168	−11.3 °C
Marginal (frost and humidity)	MALARGÜE	35°30′	69°35′	1425.0	17.1 °C	334.0	119	−15.6 °C
Not suitable	RIO GALLEGOS	51°37′	69°17′	19.0	12.3 °C	275.0	79	−13.0 °C

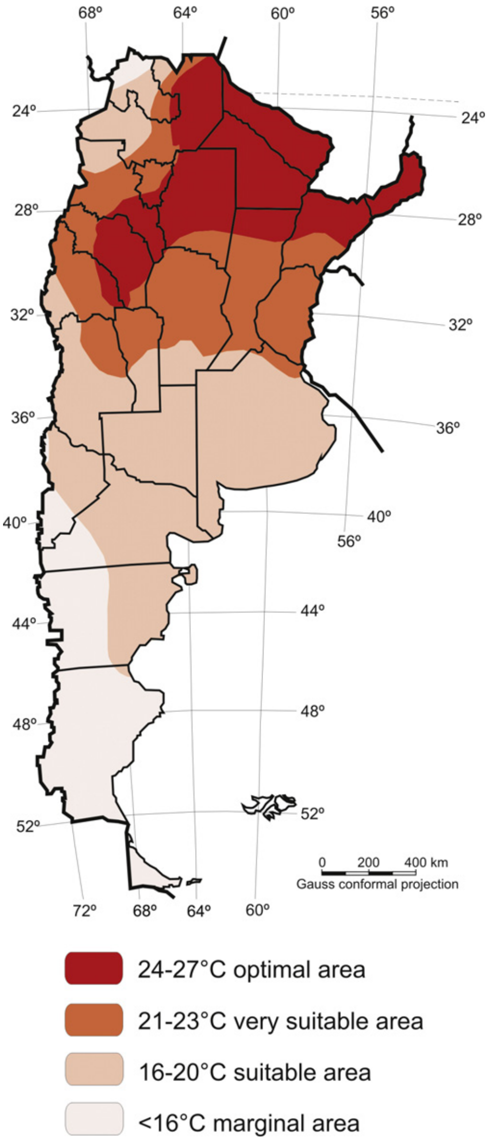

Fig. 3. Average temperature from October to February.

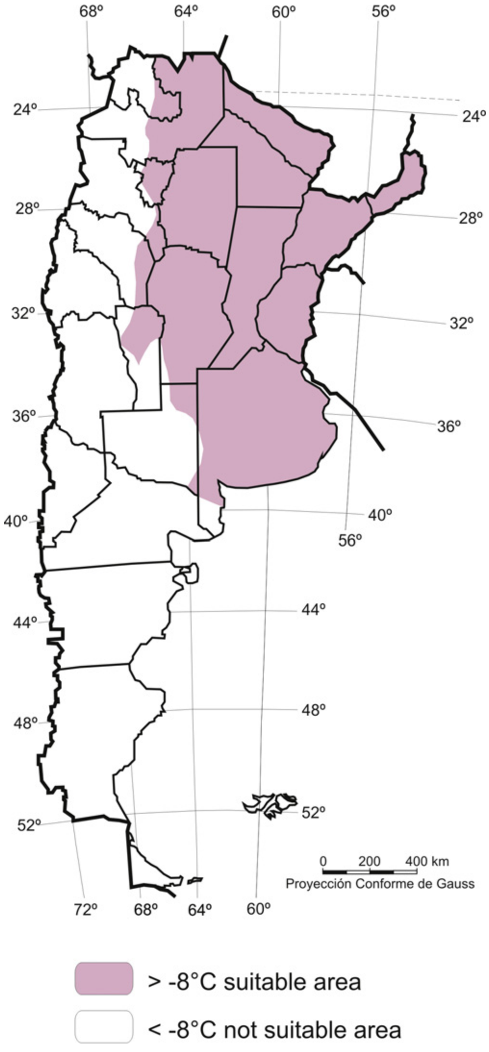

Fig. 4. Mean annual minimum temperature of −8 °C.

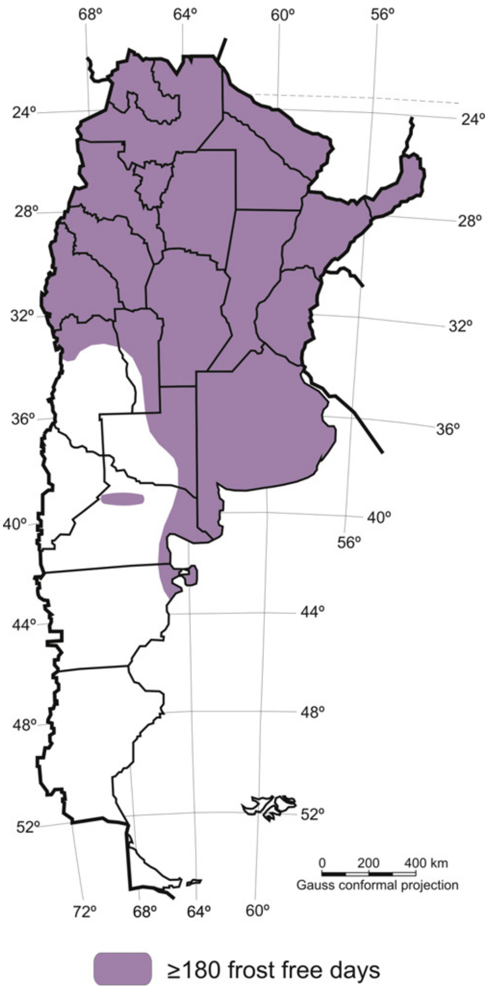

Fig. 5. Frost free days >180.

suitable (Amorim Neto et al., 1999), marking the southern and western limit of the area of castor bean dispersion due to frosts.

To analyze the water factor average annual isohyets were taken into account: 200 mm (considered by Gaydou et al., 1982), 450 mm (minimum limit assigned by EMBRAPA, 2007) and 750 mm (Távora, 1982). If the area gets below 200 mm annually, it qualifies as not suitable; in the 200–450 mm range it is marginal; between 450 and 750 mm it is suitable; and above 750 mm, it is optimal.

As there is European germplasm that resists −8 °C, this mean annual minimum temperature was considered. The areas with lower temperatures qualify as not suitable since they destroy the crop.

In Argentina there is great dispersion of mean dates of first and last frost (approximately 30 days). This means that the first frost or last frost may occur 30 days before or 30 days after the mean date. This great dispersion is due to the combined effect of the great asynchronous variability of temperature and the scarce thermal tension in the time in which frosts occur. This happens because there is easy entrance of polar air masses in the South–North direction and little annual thermal amplitude since Argentina is under maritime influence. That is why the first frosts (in autumn) with temperatures under −8 °C can kill the castor plant, in continental climate, even cultivating it as an annual crop.

Using geographical limits for the different variables, aptitude types were defined: optimal (>750 mm; temperature 24.0–27.0 °C; >−8 °C; >180 frost-free days); very suitable (>750 mm; temperature 21.0–23.9 °C; >−8 °C; >180 frost-free days); suitable with humid regime (>750 mm; temperature 16.0–20.9 °C; >−8 °C; >180 frost-free days), suitable 1 with sub-humid regime (450–750 mm; temperature 24.0–27.0 °C; >−8 °C; >180 frost-free days); suitable 2 with sub-humid regime (450–750 mm; temperature 21.0–23.9 °C; >−8 °C; >180 frost-free days); suitable 3 with sub-humid regime (450–750 mm; temperature 16.0–20.9 °C; >−8 °C; >180 frost-free days); marginal due to humidity (200–450 mm); marginal due to temperature (<16.0 °C); marginal due to frosts (<180 frost-free days or <−8 °C) and not suitable areas (combination of 2 or more of the following variables: <200 mm; <16.0 °C; <−8.0 °C; <180 frost free days).

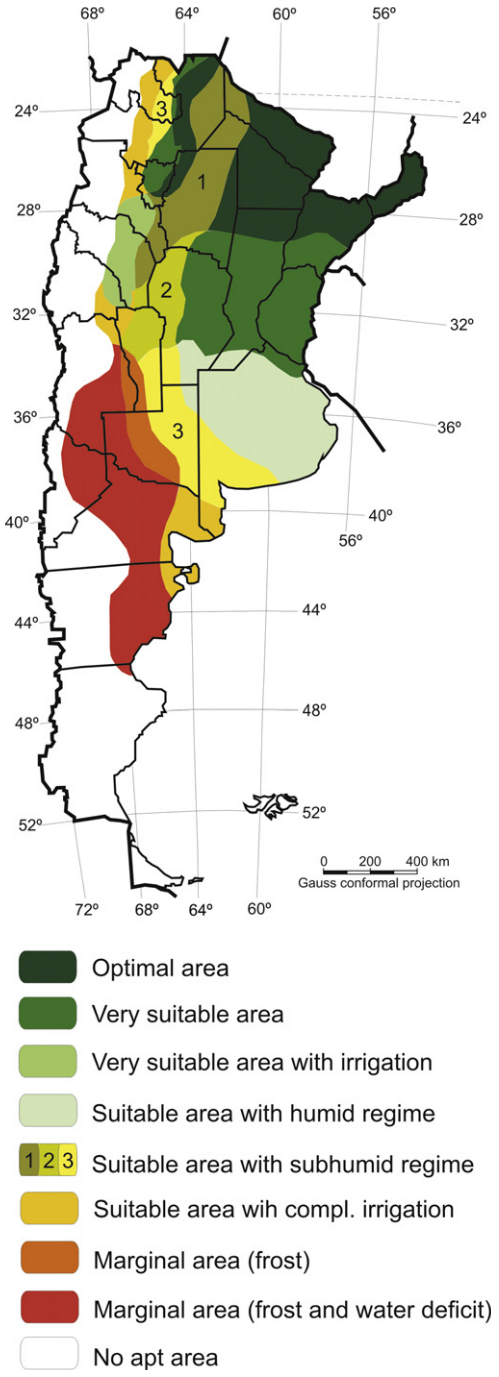

Fig. 6. Agro-climate zones.

The agro-climatic aptitude map that defined the optimal, very suitable, suitable, marginal, and not suitable areas was obtained by overlaying the maps with the different variables.

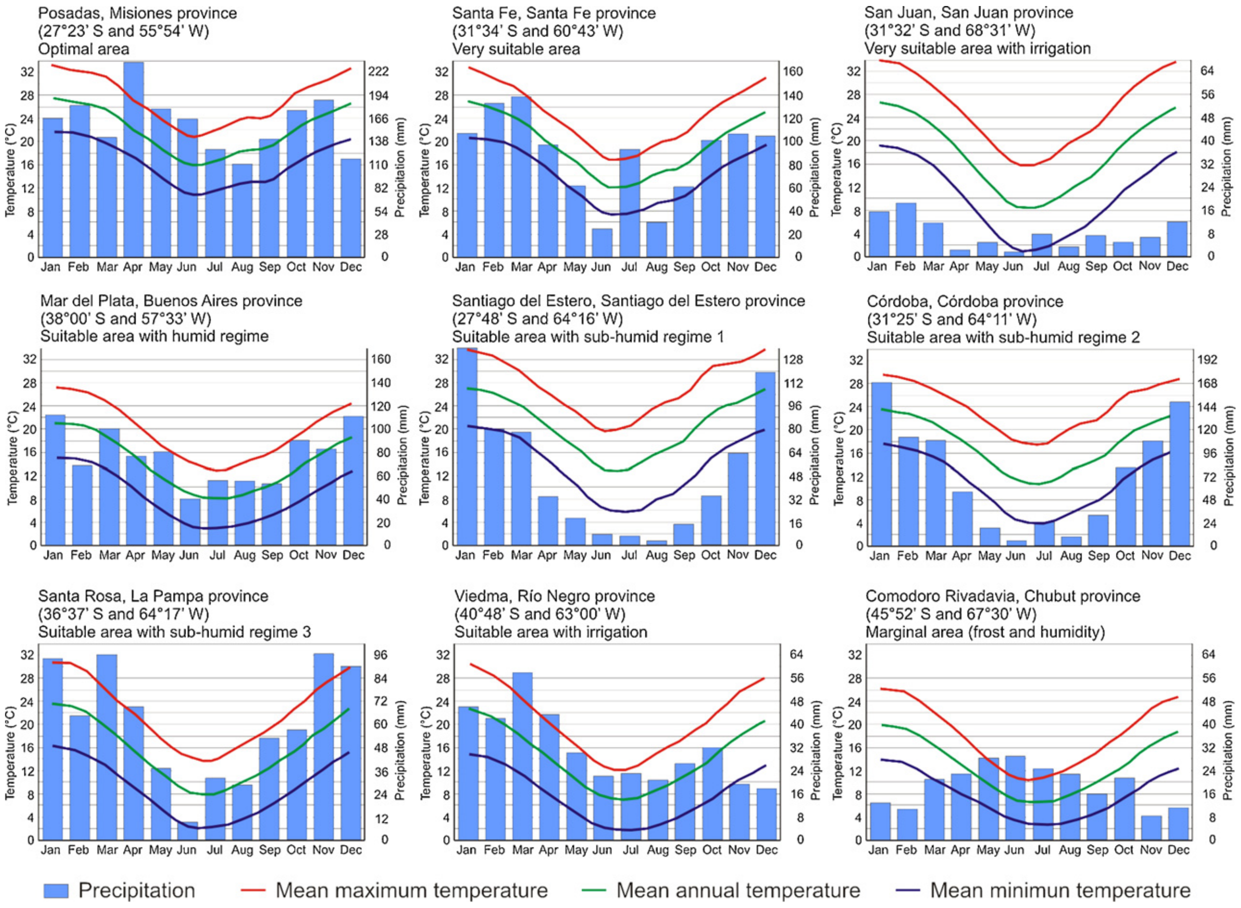

Fig. 7. Climograms from different meteorological stations.

For the purposes of the interpretation of these areas, the political map of Argentina with the toponymy of the provinces is included as Fig. 1.

To exemplify, Table 1 shows a meteorological station with geographical location, and climatic information about annual precipitation, frost-free days, mean minimum annual temperature and average temperature from October to February, for each agroclimatic type. Climograms of some meteorological stations, representative of each agroclimatic type was included.

3. Results

Fig. 2 shows annual precipitation. The marginal area is bounded by the 200 mm isohyet. Considering the isohyet of 450 mm–750 mm suitable areas are delimited. Annual rainfall over 750 mm determines optimal areas from the hydric point of view, with two subregions: the northwest and the east.

Fig. 3 shows the average temperature from October to February above 16 °C. From the NE of the province of Santa Cruz, on the border with Chubut, and continuing almost diagonally until the center of the province of Neuquén annual average temperatures are recorded above this level. To the north of this diagonal, suitable, very suitable and optimal areas are defined from the thermal point of view.

Fig. 4 delimits the areas that have a mean annual minimum temperature of −8 °C. As lower temperatures can cause crop death the areas located to the S and W of the isoline must not be considered.

The area defined in Fig. 5 by the isoline of 180 frost free days, shows the growth period for the species under conditions of semi-arid to arid climate. This isoline crosses the north of the province of Mendoza, covers almost all the province of San Luis, the east of La Pampa, the coastal area of Río Negro and the northeast of Chubut. In addition the area of artificial irrigation in the Río Negro valley is included.

Fig. 6 (obtained overlaying the maps above) shows the areas in the country where this species may be grown with success probability under rainfed conditions and with supplementary irrigation.

Fig. 7 shows climograms of 9 meteorological stations, representative of each agroclimatic type. Above each climogram is the name of the meteorological station with its geographic coordinates and the province where it is located.

Table 1 shows climatic information about annual precipitation, frost-free days, mean minimum annual temperature and average temperature from October to February, for each agroclimatic type.

4. Discussion

The areas demarcated as *optimal* and *very suitable* in the eastern sector of Argentina, overlay with the areas for the production of traditional food crops. Castor bean is not recommended for cultivation in this land unless the soils have water erosion problems. In this case it could be used as a perennial crop, as the area enjoys a frost regime which is mild for this species.

However, it may be grown in some parts of the areas classified as *suitable* (humid regime) only when the land has not been intended for food production, and also in the *suitable area 1, 2 and 3 under sub-humid regime*.

The area classified as *suitable 1* (450–750 mm, temperature 24.0–27.0 °C) covers western Formosa and Chaco, eastern Salta, most of Santiago del Estero, southeastern Catamarca and eastern La Rioja; *suitable 2* (450–750 mm, temperature 21.0–23.9 °C) comprises western Cordoba, southern Santiago del Estero, southeastern La Rioja, northern and central San Luis; *suitable 3* (450–750 mm, temperature 16.0–20.9 °C) covers southwestern Córdoba and southeastern San Luis, eastern La Pampa and southwestern Buenos Aires.

In the NW of the country with monsoonal rainfall regime there are *optimal, very suitable and suitable areas* covering part of the provinces of Salta, Jujuy and Tucumán.

There are areas that have been classified as *very suitable with irrigation and suitable with complementary irrigation*. However, any type of irrigation for this energy crop is discouraged. These areas may be intended for the cultivation of castor bean under rainfed conditions, knowing beforehand that if in a certain year rainfall is not above normal for the locality, lower yields will be obtained: lower than in suitable areas with sub-humid regime and much lower than in suitable areas with humid regime, since the yield is strongly correlated with soil water storage. No complementary irrigation is recommended for castor bean because the intensive extraction of water to irrigate this or any other energy crop could affect the availability of this resource, especially in areas with shortage problems. That is why the basic premise for the production of biofuels is to use low-productivity lands so as not to compete with the food market. The use and value of water in agriculture must be destined for food.

5. Conclusions

Considering the ability and plasticity of *R. communis* to grow under conditions of sub-humid to semiarid climate, it should be cultivated under these moisture regimes. In this way, land might be used in parts of the provinces of Salta, Jujuy, Tucumán, Chaco, Formosa, Santiago del Estero, Córdoba, San Luis, La Pampa, western Buenos Aires, La Rioja and Catamarca.

Based on International bibliography the authors were able to delineate this agro-climatic zoning model to determine potential production areas in Argentina for castor bean. This model may be applied in any part of the world, using the agroclimatic limits presented in this work.

References

Amorim Neto, M., Araújo, A., Beltrão, N., Silva, L., Gomes, D.C., 1999. Zoneamento e época de plantio para a mamoneira no Estado da Paraiba. Campina Grande: EMBRAPA-CNPA. Comunicado Técnico 108, 5 pp., http://ainfo.cnptia.embrapa.br/digital/bitstream/CNPA-2009-09/14450/1/COMTEC108.pdf.

Amorim Neto, M., Beltrão, N., Silva, L.C., 2001. Clima e Solo. In: Azevedo, D.M.; Lima, E.F. (Eds), Embrapa SPI, Brasília, p. 62–76, http://sistemasdeproducao.cnptia.embrapa.br/../Mamona.

Aslani, M.R., Malekib, M., Mohria, M., Sharifia, K., Najjar-Nezhada, V., Afshari, E., 2007. Toxicon 49, 400–406.

Azevedo, D.M., Lima, E.F., Batista, F.A., Beltrão, N.E., Soares, J.J., Vieira, R.M., Moreira, J.A., 1997. Recomendações técnicas para o cultivo da mamoneira *Ricinus communis* L. no nordeste do Brasil. Campina Grande: EMBRAPA-CNPA. Circular Técnica 25, 39 pp.

Barros Junior, G., Guerra, H.O., Cavalcanti, M.L., de Lacerda, R.D., 2008. Consumo de água e eficiência do uso para duas cultivares de mamona submetidas a estresse hídrico. Revista Brasileira de Engenharia Agrícola e Ambiental 14, 350–355, http://189.20.243.4/./engenhariaambiental/./getdoc.

Beltrão, N.E., Silva, L.C., 1999. Os múltiplos uso do óleo da mamoneira (*Ricinus communis* L.) e a importância do seu cultivo no Brasil. Revista Brasileira de Oleaginosas Fibrosas 31, 1–7.

Beltrão, N.E., 2005. Presentación: Opções Agrícolas Brasileiras para a Produção do Biodiesel, Fortaleza (Brasil), 1 de julio de 2005, http://www.ahk.org.br/inwent/palestras/napoleao_beltrao.pdf.

Carvalho, B.C.L., 1988. Cultura da mamoneira. Campinas: CATI, Comunicado técnico 73, 3 pp. Brasil.

Dai, Z., Edwards, G.E., Ku, M.S., 1992. Control of photosynthesis and stomatal conductance in *Ricinus communis* L. (castor bean) by leaf to air vapor pressure deficit. Plant Physiology 99 (4), 1426–1434.

Duke, J., 1983. Handbook of Energy Crops. Published only on the Internet, http://www.hort.purdue.edu/newcrop/duke_energy/Ricinus_communis.html.

EMBRAPA, 2006. Cultivo da Mamona. Sistemas de Produção 4. Embrapa Algodão, http://sistemasdeproducao4.cnptia.embrapa.br/../Mamona.

EMBRAPA, 2007. Cultivo da Mamona. Sistemas de Produção 11. Embrapa Clima Temperado, http://sistemasdeproducao11.cnptia.embrapa.br/../Mamona.

Falasca, S., Ulberich, A., 2006. Cultivos alternativos para la producción de biocombustibles en el área semiárida argentina. Revista Geográfica 140, 135–150, http://www.jstor.org/stable/40996734.

Freire, R.M., 2001. Ricinoquímica. O agronegócio da mamona no Brasil. Brasília. In: Azevedo, D.M.P., de Lima, E.F. (Eds.), Embrapa Informação Tecnológica: Cap. XIII, 295–335.

Gaydou, A.M., Menet, L., Ravelojaona, G., Geneste, P., 1982. Vegetable energy sources in Madagascar: ethylalcohol and oil seeds (French). Oleagineux 37 (3), 135–141.

Kumar, P.V., Ramakrishna, Y.S., Rao B.V., Victor, U.S., Srivastava, N.N., Rao A.V., 1997. Influence of moisture, thermal and photoperiodic regimes on the productivity of castor beans (*Ricinus communis* L.). Agricultural and Forest Meteorology, Amsterdam 88 (4), 279–289, available from: http://www.sciencedirect.com/science/article/pii/S0168192397000191.

Mendoza, Z.H, Reyes, T.S., 1985. Guía del cultivo de higuerilla. Boletín Divulgativo. INIAP. 1985.08. Portoviejo. Ecuador.

Reed, C.F., 1976. Information summaries on 1000 economic plants. Typescripts submitted to the USDA.

Silva, L.C, Amorim Neto, N, Beltrao, M., 2008. Recomendações técnicas para o cultivo de mamona (*Ricinus communis* L.), Campina Grande: Embrapa Comunicado Técnico, 112. Brasil.

Távora, F.J., 1982. Cultura da Mamona. Fortaleza: EPACE. 112 p. Brasil.

Thran, P., Broekhuizen, S., 1965. Agro-Ecological Atlas of Cereal Growing in Europe, Vol. 1. Agroclimatic Atlas of Europe. Elsevier, Amsterdam (NL).