ISSN: 2594-0252

AGRO PRODUCTIVIDAD

Presence of endophytic fungi in **cacao** plantations (*Theobroma cacao* L.), in the state of Tabasco, Mexico

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Año 16 • Volumen 16 • Número 10 • octubre, 2023

Colegio de Postgraduados

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Determination of optimal areas for the establishment of buffalo herds and German grass in Tabasco, Mexico

López-Castañeda, Antonio[1]; Morales-López, Reyes[1]; Reyes-Cruz, Luis Alberto[1]; Meléndez-Nava, Francisco[1]; Báez-Ruiz, Uriel Agustín[1]; Ramírez-Meneses, Aurora[1]; Calderón-Bolaina, Vinicio[1]; Torres-Hernández, José Javier[2]; Santos-Valencia, Jorge[2]; Pablo-Pérez, Maricela[2*]

[1] Colegio de Postgraduados-Campus Tabasco, Carretera Cárdenas-Huimanguillo km 3.5, C.P.86500, Cárdenas, Tabasco, Mexico.
[2] Tecnológico Nacional de México, Campus Huimanguillo, Carretera del Golfo Malpaso – El Bellote, Km. 98.1, R/a. Libertad, C.P. 86400, Huimanguillo, Tabasco.
[3] Tecnológico Nacional de México, Colonia Xoco, Alcaldia Benito Juarez, C.P. 03330, CDMX.
* Correspondence: maricela.pp@huimanguillo.tecnm.mx

ABSTRACT

Objective: To determine optimal (suitable) areas for the establishment of buffalo (*Bubalus bubalis*) herds fattened with German grass (*Echinochloa polystachya* Kunth Hitchc), based on the biophysical environmental conditions that favor the comfort of the animal species and the best development of the plant species.

Design/Methodology/Approach: An analysis of the bioclimatic parameters for water buffalo and the agroclimatic parameters for German grass was carried out in the state of Tabasco, Mexico. A comparative table of the optimal biophysical variables of water buffalo and German grass was developed from the digital soil geographic databases and the climatological normals recorded in the state of Tabasco. Edaphoclimatic maps were developed to establish buffalo herds associated with German grass, based on a cartographic cross-checking.

Results: The soil-climatic aptitude map of both species was developed at a scale of 1:135,000.

Study Limitations/Implications: Given its recent introduction, there is a lack of basic information on the edaphoclimatic conditions suitable for water buffalo in the state of Tabasco.

Findings/Conclusions: The areas for the establishment of buffalo herds and German grass were identified. Regarding their potentiality, 4.29% of the state of Tabasco is suitable, 56.67% was classified as moderately suitable, and 38.48% is not suitable.

Keywords: *Bubalus bubalis*, geographic information system, map algebra.

Citation: López-Castañeda, A., Morales-López, R., Reyes-Cruz, L. A., Meléndez-Nava, F., Báez-Ruiz, U. A., Ramírez-Meneses, A., Calderón-Bolaina, V., Torres-Hernández, J. J., Santos-Valencia, J., & Pablo-Pérez M. (2023). Determination of optimal areas for the establishment of buffalo herds and German grass in Tabasco, Mexico. *Agro Productividad*. https://doi.org/10.32854/agrop.v16i10.2486

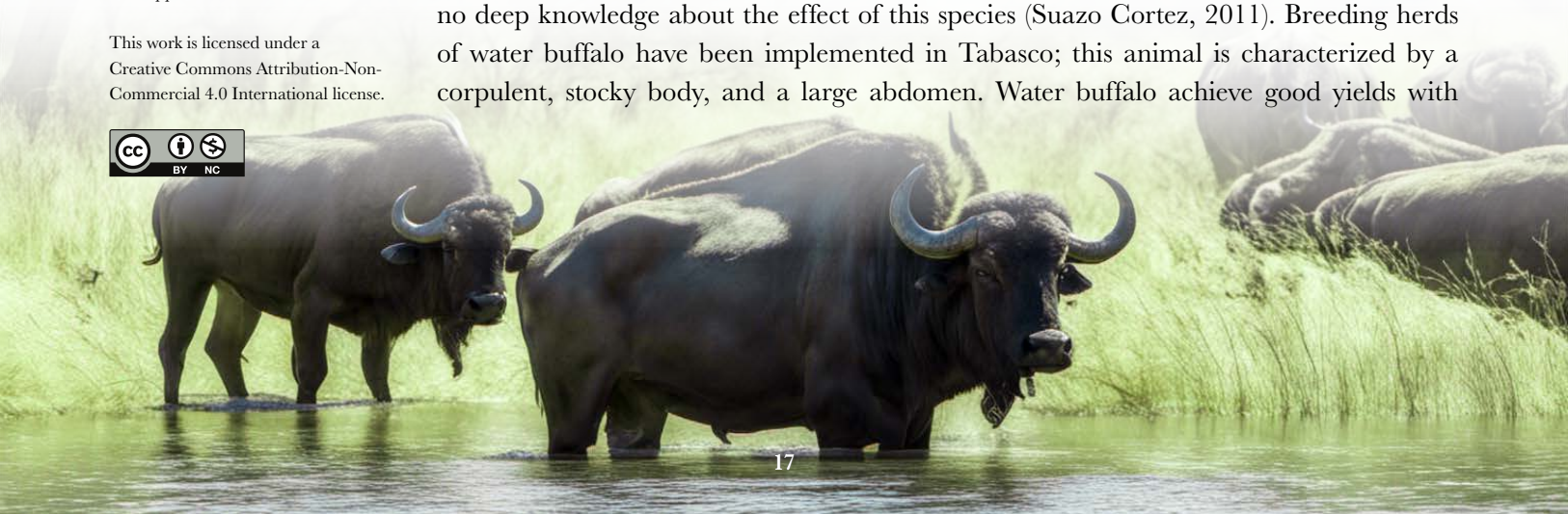
Academic Editors: Jorge Cadena Iñiguez and Lucero del Mar Ruiz Posadas

Received: January 26, 2023.
Accepted: September 17, 2023.
Published on-line: December 07, 2023.

Agro Productividad, 16(10). October. 2023. pp: 17-25.

INTRODUCTION

Since water buffalo has only been recently introduced to Tabasco, Mexico, there is no deep knowledge about the effect of this species (Suazo Cortez, 2011). Breeding herds of water buffalo have been implemented in Tabasco; this animal is characterized by a corpulent, stocky body, and a large abdomen. Water buffalo achieve good yields with



diverse forages, regardless of their bromatological quality (Pérez, 2007) and the areas where they are established.

Tabasco is located in the humid tropical zone, with regions below sea level (García, 2004); therefore, it has the flood plain and climate conditions necessary for the establishment of buffalo herds. Buffalo is a species with comparative advantages over cattle, since it develops faster, consequently reducing costs (Álvarez *et al.*, 2005; Zava, 2012).

Animals need optimal environmental conditions for their production and comfort. Therefore, to successfully establish the species, the areas in the state of Tabasco which meet these requirements should be determined. Since these aspects are currently being omitted in the state by those interested in establishing buffalo herds, they could be introduced to places that are not optimal for the animals. Consequently, optimal areas were located for the establishment of buffalo herds associated with German grass, which has been identified as a species with propitious characteristics for the development of the animal (Camarao *et al.*, 2004). Likewise, Meléndez-Nava (2012) has argued that German grass is a species that reaches its maximum use under conditions of permanent flooding —which is likewise favorable for water buffalo. Therefore, the objective of this research was to determine which areas are suitable to establish herds of buffalo (*Bubalus bubalis*) for fattening purposes, associated with German grass (*Echinochloa polystachya*), based on the environmental conditions that favor the comfort of both species.

MATERIALS AND METHODS

The study area covered the state of Tabasco, Mexico (17° 15' 03" and 18° 39' 03" N, and 90° 59' 15" and 94° 07' 48" W). It has a total area of 24,661.0 km^2 (INEGI, 1998). It is bounded by the Gulf of Mexico to the north, the state of Campeche to the northeast, the Republic of Guatemala to the southeast, the state of Chiapas to the south, and the state of Veracruz to the west (Figure 1).

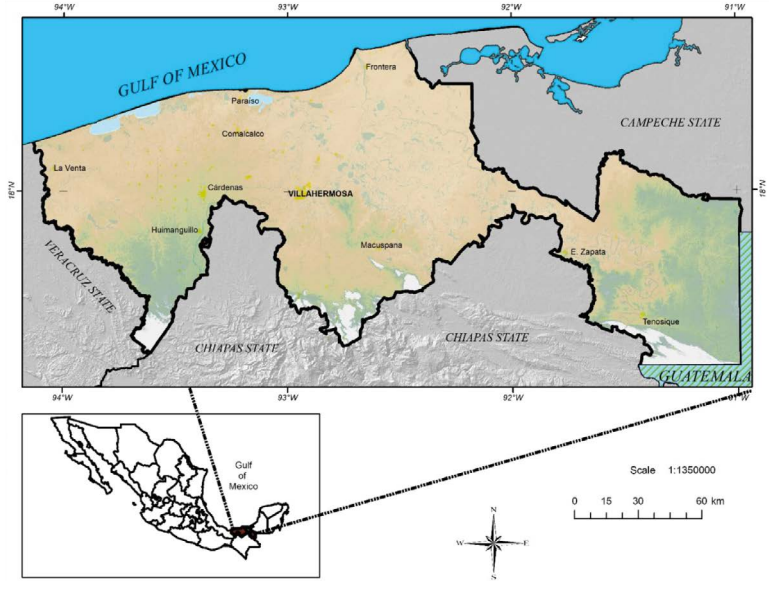


Figure 1. Location of the State of Tabasco, Mexico (study area).

Bioclimatic conditions for water buffalo and agroclimatic conditions for German grass

The main bioclimatic and agroclimatic variables were considered to determine the areas with optimal potential. For this purpose, documentary information was compared in the main research centers of the region, building a database that was systematized with Microsoft Excel 2010. The categories were: name of the author, title, year of publication, origin of the information, and suggested ranges for each variable under study. The database was used to classify the variables by optimal ranges for each species; the arithmetic mean was obtained for the abovementioned ranges. The edaphic variables indicated in Table 1 were computed using Microsoft Excel 2010 and the optimal values for the state of Tabasco were used to classify the soil types in three categories (Palma-López *et al.*, 2007): suitable (Su), moderately suitable (MSu), and not suitable (NSu).

Bioclimatic and agroclimatic analysis

The climate was analyzed using historical records (1951 to 2010) of the climatological normals of the state of Tabasco (Servicio Meteorológico Nacional [SMN], 2022). The classification of the geographical location according to the name, temperature, and precipitation of the climatological stations was incorporated into the GIS software (ArcGis version 10.1); the IDW (Inverse Distance Weighted) method (ESRI, 2022) was used to interpolate the isohyet and isotherm maps. Once the coverage was obtained, the areas with the optimal ranges for the establishment of buffalo herds associated with German grass (B-G) were identified, based on which maps of the areas with bioclimatic and agroclimatic potential were developed.

Soil analysis

The evaluation of the soil resource for the water buffalo was based on the units of the FAO/UNESCO system (IUSS Working Group WRB, 2015), using four variables: depth, slope, drainage, and altitude. Meanwhile, seven variables were taken into consideration in the case of German grass: depth, fertility, texture, pH, slope, drainage, salinity, and aluminum toxicity. Consequently, the limiting elements allowed an approximation of

Table 1. Bioclimatic and agroclimatic variables used for the zoning of water buffalo and German grass.

Species	Soil variable	Climatic variable	Geographic variable
Buffalo	• Depth (m) • Texture (%) • Slope (%) • Drainage (m)	• Total annual precipitation • Average annual temperature • Average minimum temperature • Average maximum temperature	Altitude (msnm)
German Grass	• Depth (m) • Fertility • Texture (%) • pH • Slope (%) • Drainage • Salinity • Aluminum toxicity		

regions suitable for the B-G binomial. The subsequent identification of the pedological units —based on the 1:250,000 scale mapping of the state of Tabasco (Palma-López *et al.*, 2007)— enabled the selection of suitable soils (Su). The selection of the edaphic units led to the development of maps with edaphic potential for the establishment of the B-G binomial.

Crossing and cartographic analysis

With the climatic and soil maps of the state of Tabasco, a super positioning of the cartography was carried out with the ArcGis 10.1 software (ESRI, 2022); map algebra was used to generate areas with different edaphoclimatic potential for the B-G binomial.

RESULTS AND DISCUSSION

Climatic requirements for water buffalo

According to the analysis of the existing bibliographic information for the establishment of buffalo herds, the optimal temperatures vary from 27.1 °C to 28.9 °C. The optimal precipitation ranges between 2,000 and 3,314 mm (annual average: 3,313.99 mm), at an altitude of 0-50 m.a.s.l. These results match the data reported by Das *et al.* (1999), who point out that a >30 °C environmental temperature would cause the animal to gasp, because of the heat stroke. The spatial distribution of temperature per suitable municipality in the state of Tabasco indicates that 28.99% of the territory is Su for establishing buffalo herds, while 67.55% is MSu; therefore, it could be inferred that temperature is not a limiting factor for the establishment of buffalo herds, since only 3.45% of the territory was NSu. According to their total annual precipitation, the areas of the state with potential for the establishment of buffalo herds are divided as follows: 68.47% is Su, while 17.00% is MSu, and only 14.53% is NSu. The areas that met the temperature and precipitation conditions were called bioclimatic: 21.22% of the surface of the state were Su for the establishment of the animal, while 61.35% was MSu, followed by a 17.43% of NSu areas.

Soil aptitude for the establishment of buffalo herds

Deep clay soils, with a <20% slope and poor drainage (Palma-López *et al.*, 2007) do not involve any drawbacks for the establishment of buffalo herds. Therefore, three groups of Su soils identified in Tabasco accounted for 44.05% of the total surface of the state that report waterlogging in rainy seasons (an environment necessary for the comfort of buffalo herds), while 20.76% comprise five groups cataloged as MSu and 35.19% were classified as part of the NSu soil group (Table 2).

Edaphoclimatic requirement for the establishment of buffalo herds

Table 3 shows the results of the edaphoclimatic geospatial analysis for the establishment of buffalo herds. Of the total area of the state, 10.37% is Su for the establishment of this species; 54.09% is classified as MSu and therefore some areas can become optimal, if an adequate management of the soil (drainage, slope, etc.) is carried out; and 35.07% was classified as NSu —*i.e.*, unsuitable (or at the very least unprofitable), even with management.

Table 2. Soil groups in the state of Tabasco, with different aptitude for the establishment of buffalo herds.

Code	Group	Aptitude	(%)
GL	Gleysol	suitable	44.05
HS	Histosol	suitable	
VR	Vertisol	suitable	
AC	Acrisol	moderately suitable	20.76
CA	Cambisol	moderately suitable	
FR	Ferrasol	moderately suitable	
FL	Fluvisol	moderately suitable	
RG	Regosol	moderately suitable	
Al	Alisol	not suitable	35.19
AR	Arenosol	not suitable	
LP	Leptosol	not suitable	
LV	Luvisol	not suitable	
PL	Plintisol	not suitable	
SC	Solonchaks	not suitable	

Table 3. Area with different soil-climatic aptitude for the establishment of buffalo herds in the state of Tabasco, Mexico.

Soil-Climatic Aptitude	Area	
	(%)	Ha
Suitable	10.37	256547.02
Moderately	54.09	1338099.44
Not Suitable	35.07	867609.25
Total	100	2473527.41

Figure 2 shows the map of soil-climatic aptitude for the establishment of buffalo herds in the state of Tabasco. The most representative areas are identified in yellow and are cataloged as MSu.

Bioclimatic requirements of German grass

For German grass (*Echinochloa polystachya*), the areas with high climatic and edaphic potential were taken, based on their optimal values, as established by ECOCROP (FAO, 2022).

Characteristics of German grass

German grass is a species that is successfully cultivated from 0 to 100 m.a.s.l., in the lowlands near the Gulf of Mexico (Enríquez *et al.*, 2015). It is a perennial species, which resists frequent and prolonged (up to six-month long) flooding (Enríquez *et al.*, 2015).

It tolerates a wide range of soils, although its growth is jeopardized when the lack of water is evident (Meléndez-Nava, 2012); ideally, this type of grass should be grown under

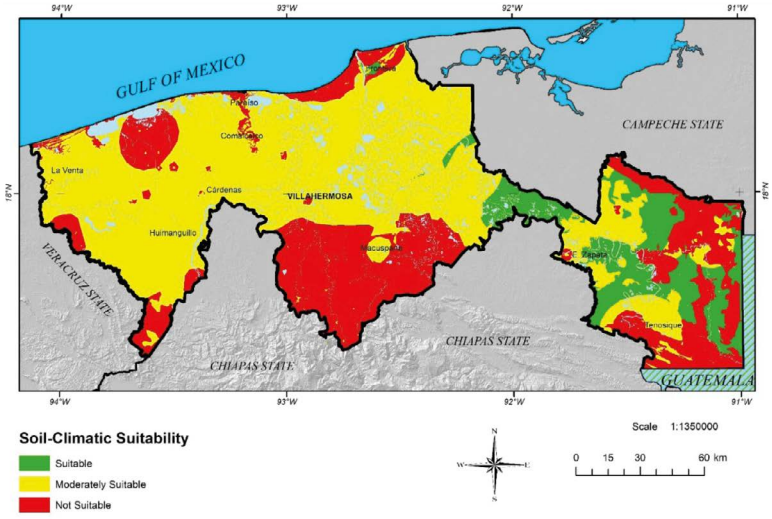


Figure 2. Areas with edaphoclimatic suitability for the establishment of buffalo herds in the state of Tabasco, Mexico.

waterlogging conditions. Meléndez-Nava (2012) mentions that, in Tabasco, German grass has an excellent growth in Gley type soils, adapts to soils with a pH of 4.0 to 8.0, has some resistance to alkalinity, and is highly tolerant to poor drainage —a fact that is also supported by the FAO (FAO, 2022).

Authors such as Enríquez *et al.* (2015) and Meléndez-Nava (2012) indicate that it is tolerant to approximately 2.8 mmhos/cm; nevertheless, according to the latter author, its yields are jeopardized, although they can grow under very high precipitation (>3,000 mm), and overall they do not have a good "growth in drought conditions, unless there is a high-water table or the soil retains reserve moisture" (Meléndez-Nava, 2012, p.187).

The resulting climatic conditions indicated that, according to their temperatures, the zones of the Tabasco territory in which German grass should be established are divided as follows: 80.35% were Su, followed by 17.06% MSu, and only 2.58% NSu. The spatial distribution of the precipitation data indicates that 70.96% of the territory of the state of Tabasco meets Su conditions for the establishment of pasture, while 29.01% is classified as MSu. Just like in the case of the temperature condition, Tabasco does not present limitations for the establishment of German grass, since only 0.01% of the total territory was classified as NSu. Based on the cross-checking of temperature and precipitation information, it was designated as agroclimatic: 54.89% of the state of Tabasco is Su for the establishment of pasture, while 42.50% is MSu and only 2.59% is registered as NSu. Table 4 shows the relative values resulting from the different edaphic aptitudes for German grass. This table shows that 59.77% of the state is edaphically Su, 16.17% is MSu, and 24.05% is NSu.

Figure 3 shows that the geospatial analysis of the agroclimatic and edaphic information indicated that 34.30% of the surface of the state is edaphoclimatically Su for the establishment of German grass, while 39.40% is MSu, and 26.30% is NSu.

Table 4. Area of the different soil aptitudes for German grass (*Echinochloa polystachya*) in the state of Tabasco, Mexico.

Soil Aptitude of german grass	Area	
	(%)	Ha
Suitable	57.77	1478505.76
Moderately	16.17	399986.30
Not Suitable	24.05	595093.4
Total	100	2,473,527.41

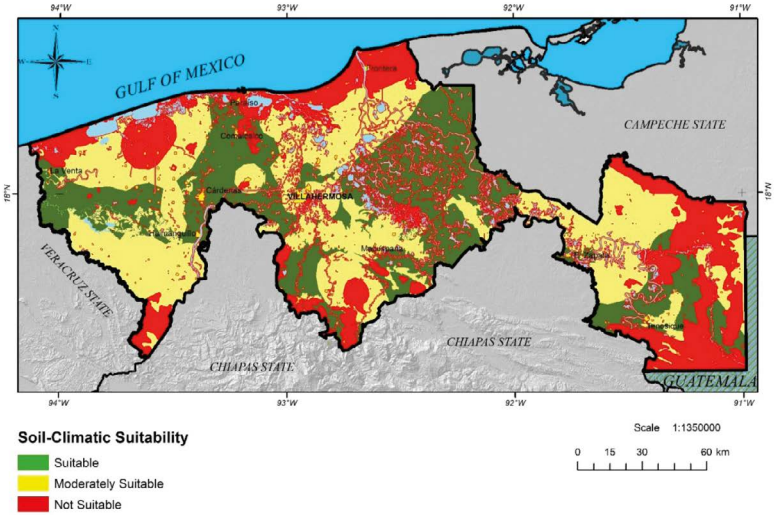


Figure 3. Areas with edaphoclimatic aptitude for the establishment of German grass (*Echinochloa polystachya*) in the state of Tabasco, Mexico.

The cross-checking of the edaphoclimatic information for the B-G binomial led to the differentiation of the following areas: 4.29% of the state area has Su edaphoclimatic potential for B-G; therefore, buffalo herds could be established in these areas and, since the comfort of the animal and its food would be guaranteed, good returns would be obtained. Meanwhile, 56.67% is MSu and establishing a buffalo herd in these areas is feasible; however, some type of soil management would be necessary, mainly to achieve optimal yields. Finally, 38.48% of the state was identified as NSu for the establishment of a productive herd. In Figure 4, the suitable areas are identified in green; they are located in the central part of the municipality of Balancán, southern Jonuta; the municipality of Emiliano Zapata is also found in the central and southern areas of the municipality. The areas with moderately suitable potential are in the central region of the state of Tabasco and include the municipalities of Cárdenas, Huimanguillo, Centro, Centla, and Jonuta, among others. The unsuitable areas for the establishment of the B-G binomial are highlighted in red; they are located mainly in the North and South areas of the state, due to the presence of sandy or stony soils, as well as altitudes higher than the two species under study can resist.

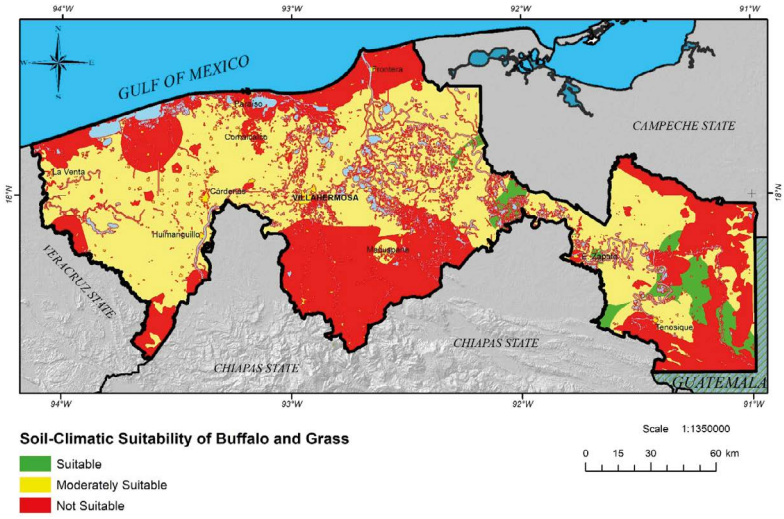


Figure 4. Areas with edaphoclimatic suitability for the establishment of buffalo herds (*Bubalus bubalis*) and German grass (*Echinochloa polystachya*) in the state of Tabasco, Mexico.

CONCLUSIONS

Out of all the whole area of the state of Tabasco, 10.37% and 34.30% are edaphoclimatically Su for the establishment of buffalo herds and German grass, respectively. Meanwhile, 4.29% of the total area of the state of Tabasco was identified as Su edaphoclimatic zones for the establishment of the B-G binomial.

REFERENCES

Álvarez, J. R. L., Elías, A., & Sánchez, O. F. (2005). ¿Por qué el búfalo de agua presenta mayor eficiencia productiva que los vacunos? REDVET. *Revista Electrónica de Veterinaria, VI*(11), 1-6. https://www.redalyc.org/articulo.oa?id=63617170003

Camarao, A. P., Jr, J. B. L., Dutra, S., Hornick, J.-L., & Silva, M. B. D. (2004). Grazing buffalo on flooded pastures in the Brazilian Amazon region: A review. *Tropical Grasslands*, 38, 193-203. https://tropicalgrasslands.info/index.php/tgft/pages/view/tropicalGrasslands

Das, S. K., Upadhyay, R. C., & Madan, M. L. (1999). Heat stress in Murrah buffalo calves. *Livestock Production Science, 61*(1), 71-78. https://doi.org/10.1016/S0301-6226(99)00040-8

Enríquez, J. F., Hernández, A., Quero, A. R., & Martínez, D. (2015). Producción y manejo de gramíneas tropicales para pastoreo en zonas inundables (Folleto N.o 60; p. 60). INIFAP - Colegio de Postgraduados. https://www.researchgate.net/publication/280082284_Produccion_y_Manejo_de_Gramineas_Tropicales_para_Pastoreo_en_Zonas_Inundables

ESRI. (2022). ArcGIS [software GIS] (10.1) [VBA]. ESRI. https://www.esri.com/en-us/home

FAO. (2022). ECOCROP. https://gaez.fao.org/pages/ecocrop

García, E. (2004). Modificaciones al sistema de clasificación climática de Köppen (5ta.). Universidad Nacional Autónoma de México. https://www.academia.edu/12911044/Modificaciones_al_sistema_de_clasificaci%C3%B3n_clim%C3%A1tica_de_K%C3%B6ppen_para_adaptarlo_a_las_condiciones_de_la_Rep%C3%BAblica_Mexicana_2004_Enriqueta_Garc%C3%ADa

INEGI. (1998, enero 1). México en cifras. Instituto Nacional de Estadística y Geografía. INEGI. https://www.inegi.org.mx/app/areasgeograficas/

IUSS Working Group WRB,. (2015). Base referencial mundial del recurso suelo 2014, Actualización 2015. Sistema internacional de clasificación de suelos para la nomenclatura de suelos y la creación de leyendas de mapas de suelos. https://www.fao.org/soils-portal/soil-survey/clasificacion-de-suelos/base-referencial-mundial/es/

Meléndez-Nava, F. (2012). Principales forrajes para el trópico (1ra.). Yax-Ol.

Palma-López, D. J., Cisneros, D. J., Moreno, C. E., & Rincón-Ramírez, J. A. (2007). Suelos de Tabasco: Su uso y manejo sustentable (Vol. 195). COLEGIO DE POSTGRADUADOS-ISPROTAB-FUNDACIÓN PRODUCE TABASCO.

Pérez, Y. A. (2007). El búfalo, una opción de la ganadería. REDVET. *Revista Electrónica de Veterinaria, VIII*(8), 1-23. https://www.redalyc.org/articulo.oa?id=63612734014

Servicio Meteorológico Nacional [SMN]. (2022). Normales Climatológica por Estado. https://smn.conagua.gob.mx/es/informacion-climatologica-por-estado?estado=tab

Suazo Cortez, R. (2011). Seroprevalencia de brucelosis en búfalos de agua (*Bubalus bubalis*) en tres unidades de producción localizadas en los municipios de Isla y Juan Rodríguez Clara, Veracruz, México. [Licenciatura, Médico Veterinario Zootecnista, Universidad Veracruzana]. https://www.uv.mx/personal/avillagomez/files/2012/12/Suazo-2011.-Brucelosis-en-bufalos.pdf

Zava, M. A. (2012). Present situation and future perspective of buffalo production in America. *J Anim Plant Sci, 22*(3), 262-226. http://www.thejaps.org.pk/docs/Supplementary/03/028.pdf