

AGRO-CLIMATIC ZONING TO BANANA-GROWING IN THE MESOREGION OF VALE DO RIO DOCE¹

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ABSTRACT - This study aims at identifying by zoning the mesoregion of Vale do Rio Doce edaphoclimatic aptitude for the commercial production of banana. The factors used in the agro-climatic zoning were temperature, altitude, rainfall, water deficit and soil type. Information on the thermal conditions was acquired from the INMET and also using estimates from a mathematical model. Altimetry data were acquired using digital elevation model generated from ASTER images. Rainfall data were collected from literature and from the ANA. To obtain the data of water deficit a standard water balance was calculated. Soil information was provided by Geominas Program. According to the results it was evident that banana can be grown with the use of irrigation in 28.7% of the zoned area (about 11,000 km²) emphasizing Guanhães, Mantena and Aimorés microregion. It was clear that 71.3% from the mesoregion is unsuitable to produce bananas because of the altitude and soil type. Moreover it was also clear that the mesoregion of Vale do Rio Doce has no preferential and suitable areas for the cultivation of unirrigated banana.

Index terms: *Musa* spp., zoning, mesoregion of Vale do Rio Doce.

ZONEAMENTO AGROCLIMÁTICO PARA A CULTURA DA BANANA NA MESORREGIÃO VALE DO RIO DOCE – MG

RESUMO - O objetivo desta pesquisa foi identificar, por meio de zoneamento, a aptidão edafoclimática da mesorregião do Vale do Rio Doce para a produção comercial de banana. Os fatores utilizados no zoneamento agroclimático foram temperatura, altitude, precipitação, deficiência hídrica e tipo de solo. As informações sobre as condições térmicas foram obtidas do Instituto Nacional de Meteorologia e por meio de estimativas de modelo matemático. Os dados altimétricos foram obtidos por meio do modelo digital de elevação, gerado a partir de imagens ASTER da mesorregião. Os dados de precipitação foram coletados da literatura e da Agência Nacional de Águas. Para a obtenção dos dados de deficiência hídrica, foi calculado o balanço hídrico normal. As informações de solo foram adquiridas do Programa GeoMinas. A pesquisa evidenciou que a bananeira pode ser cultivada com o uso de irrigação, em 28,7% da área zoneada (1,1 milhão de hectares), com destaque para as microrregiões de Guanhães, Mantena e Aimorés. Por outro lado, 71,3% da mesorregião são inaptas para o cultivo da banana, em função da altitude e do tipo de solo. A mesorregião do Vale do Rio Doce não possui áreas preferenciais e/ou aptas ao cultivo de sequeiro da banana.

Termos para indexação: *Musa* spp., zoneamento, Vale do Rio Doce.

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INTRODUCTION

Fruit growing is an activity that has contributed significantly to national economic development, due to its capacity of employment and income generation in the agribusiness chain. This activity generates about five million jobs and accounts for 25% of national agricultural production. Brazil is the world's third largest fruit producer, with 43.6 million tons harvested in 2.2 million hectares. 53% of this production is destined for the fresh fruit market and the remaining 47% for the processed fruit. Brazilian fruit growing is practiced with tropical, subtropical and temperate fruits due to the territorial extension of the country, geographical position, different soil types and different climatic conditions. There are 500 native edible fruit species, 220 of them found in the Amazon (CNA, 2013; IBRAF, 2013).

Among the fruits produced and commercialized in the country, banana (*Musa* spp.) occupies a prominent position. Brazil was the sixth largest fruit producer in 2012 (SALOMÃO; SIQUEIRA, 2015). Minas Gerais accounts for 8.9% of national production, represented by 654,000 tons harvested in 41,400 hectares (IBGE, 2014). The consumer market is the applicant of the fruit to the growing urban populations. Its consumption fresh and as raw material for products such as sweets, flour, dry banana and handcraft has increased considerably in the recent years. According to FAO, Food and Agriculture Organization of the United Nations, Brazilians reached an average consumption per capita year of 29.1 kg of banana, two and a half times the world average consumption (FAO, 2014). This high consumption is due to the knowledge of the nutritional value of the fruit, associated to the excellent flavor and low market price.

The consumer market for bananas responds positively to the introduction of initiatives of new products and new producing regions. These new regions, when present edaphoclimatic conditions satisfying the demands of the culture, contribute to increase productivity and banana quality. In this context, the mesoregion of Vale do Rio Doce has characteristics that qualify it for the cultivation of bananas. It is the sixth largest mesoregion of the state in area, with 41,809.87 km², and has fertile soils and high temperatures suitable for tropical fruit cultivation and long-cycle plants such as banana. In addition, the Vale do Rio Doce present to be economically stagnated requiring incentives for the establishment of banana plantations in order to improve life quality of the population and boost regional development. The knowledge of

edaphoclimatic conditions of Vale do Rio Doce is important for evaluating the eventual deployment and/or establishment of commercial banana crop. Such knowledge is possible by agroclimatic zoning.

If understood the concept of Wollman and Galvani (2013), the zoning is the technique of delimitation of aptitude of growing regions as the climate and soil factors in macroclimatic and regional scales. It is used to identify and delimitate areas suitable for crops or subject to climate risks or fitodisease escape (PEREIRA et al. 2002; SENTELHAS; MONTEIRO, 2009). This is a technique of specialization of one or more combined information (SENTELHAS; MONTEIRO, 2009). In zoning, low resolution images and low quality interpolators can compromise the accuracy of the results. The interpolation of spatial data is a tool used to estimate any numeric variable in a point where its measurement was not performed. The geostatistical interpolation ponders the neighbors of the point to be estimated, in a not tendentious manner and with minimum variance to generate not biased maps (AKKALA et al., 2010). The quality of data spacialization provided by different interpolators has not received proper attention. The zoning is subject to incorporation of new study methodologies, larger number of variables, with more consistent data sets and use of interpolators that present more effective results (PEZZOPANE et al., 2012).

The Ministry of Agriculture, Livestock and Supply (MAPA) has made climate risk zoning for banana in the state of Minas Gerais, identifying municipalities able for cultivation and the planting periods with less climatic risk for the culture (BRASIL, 2010). Agroclimatic zoning have been prepared for fruit trees like avocado (ZARO et al., 2014) and macadamia nut (SCHNEIDER et al. 2012).

In this study we used the agro-climatic zoning for banana in the mesoregion of Vale do Rio Doce, in accordance with the methodology used by MAPA, adding altimetry data with the use of higher resolution satellite images.

MATERIAL AND METHODS

The mesoregion of Vale do Rio Doce has 140 municipalities allocated in the regions of Aimorés, Caratinga, Governador Valadares, Guanhães, Ipatinga, Mantena and Peçanha. It is located in the east of the state, between latitudes 18 ° 49 '12 "and 19 ° 03' 00 " South and meridians 40 ° 49 '18" and 43 ° 33' 36 "west of Greenwich and occupies an area of 41,791 km² (Figure 1).

For drawing up the agro-climatic zoning

it was considered the factors: rainfall, altitude, type and class of soil aptitude, temperature and water stress. For each factor has been established the parameter for the agricultural potential of the commercial banana, according to the criteria of culture requirements (ALVES et al., 1999; PEREIRA et al., 2007; RODRIGUES et al., 2008; COELHO et al. 2009) (Table 1):

a) average temperature higher than 18°C and lower than 35°C. The average of 28 ° C was considered preferential;

b) Average annual rainfall between 1,200 mm and 1,900 mm, being 1,900 mm preferential;

c) altitude from 0 to 300 m;

d) water deficit lower than 100 mm;

e) soils Groups I and II (Table 2).

In accordance with the above criteria were defined classes of aptitude for cultivation: preferential, suitable, suitable with irrigation, suitable with soil management, restricted by altitude, restricted by soil and inept (Tables 1 and 2). These classes allow you to identify suitable and inapt regions and with specific restrictions per variable evaluated.

Information on thermal conditions was obtained from the weather stations of the National Institute of Meteorology (INMET) located in the municipalities of Aimorés and Caratinga, with historical series of 22 years. However, considering the lack of information on meteorological data it was necessary to use models such as multiple regression equations (SEDIYAMA; MELO JUNIOR, 1998; MEDEIROS et al., 2005). For sites deprived of information, it was estimated the average annual temperature by means of regression equations, using the geographical coordinates and the altitude of the desired point. Thus it was also used data from meteorological stations of Hydrological Information System (HIDROWEB) of the National Water Agency (ANA) which, together with INMET stations totaled 102 points, complementing the spatial data.

The altimetry data were obtained from the digital elevation model (DEM) generated from ASTER images (Advanced Spaceborne Thermal Emission Reflection Radiometer) of October 2011, whose resolution has 30 m with vertical error of 7 to 14 m, using geographic projection system WGS84 (World Geodetic system) (ASTER, 2013).

Rainfall data of the mesoregion of Vale do Rio Doce were obtained from Guimarães et al. (2004) and ANA, resulting in 51 historical series. The data series of the ANA's HIDROWEB system were selected on the basis of the collection duration (over 30 years), of its continuity and of the result of the consistency analysis.

To calculate the soil water deficit for banana plant it was used the normal hydric balance proposed by Thornthwaite and Mather (1955), from the spreadsheet developed by Rolim et al. (1998). It was taken as the amount of available water capacity in the soil (AWC) 100 mm, to be considered an average value for the culture according to Pereira et al. (2002). The normal water balance resulted from the joint analysis of temperature and average monthly precipitation of each station considered. The monthly average rainfall data were also obtained from the INMET weather stations and stations used to estimate the average monthly temperature.

Information on soil types have been acquired from the Integrated Use Program of Geoprocessing from the Government of Minas Gerais (Geominas). The Geographic Information System (GIS) used to generate the maps and perform their crossing was the ArcGIS version 10, with kriging interpolation methods for the generation of temperature maps and IDW (Inverse Distance Weighted) for the remaining maps. GIS and spatial interpolation techniques may be revised in Akkala et al. (201

RESULTS AND DISCUSSION

Considering the demands of the culture, the optimum temperature is 28 °C, with a minimum of 18 °C and maximum 35 °C. The banana tree should not be grown in areas with minimum temperature below 15 °C, as there is paralysis of their metabolic activity or above 35 °C when occurs the paralyzation of its development by dehydration of the leaves (ALVES et al., 1999; PEREIRA et al., 2007; RODRIGUES et al., 2008; COELHO et al. 2009). It is verified that the mesoregion of Vale do Rio Doce has, throughout its length, thermal conditions favorable to the cultivation of banana tree to present annual average temperatures within the required range (18 ° to 35 °C) for the good development of crops (Figure 2). Regarding the altitude, the range from 0 to 300 m was considered ideal for maximum productivity of banana tree (ALVES et al., 1999; PEREIRA et al., 2007; RODRIGUES et al., 2008; COELHO et al. 2009). It is known that in regions with altitude above 300 m the banana tree increases the duration of the production cycle. It is noted that more than 30% of the area of the mesoregion of Vale do Rio Doce (12,832 km²) has altitudes within the ideal range for growing (Figure 3). More than 65% of the mesoregion area (27,532 km²) presents altitudes within the acceptable range (between 0 and 900 m) for banana production, and only 3.4% of the area

has altitude above 900 m, considered inappropriate (Table 1, Figure 3).

Regarding precipitation, the culture requires an average of 1,900 mm well distributed throughout the year. The consumption of water by the plant is high and constant, due to its morphology and hydration of the tissues. Annual rainfall below 1,200 mm restricts the cultivation of banana tree, as difficult or prevents the release of the inflorescence (ALVES et al., 1999; PEREIRA et al., 2007; RODRIGUES et al., 2008; COELHO et al. 2009). Thus, the mesoregion of Vale do Rio Doce have 34.3% of its area (14,332.8 km²) suitable for cultivation having average annual rainfall within the acceptable range (1,200-1,900 mm) for fruit production and 65.7 % of its area (27,456.5 km²) unsuited to cultivation to present annual average rainfall below 1,200 mm (Figure 4).

For water deficit, the annual limit considered acceptable for the banana cultivation is 100 mm. The deficit above 100 mm reduces plant productivity and the quality of its fruit (ALVES et al., 1999; PEREIRA et al., 2007; RODRIGUES et al., 2008; COELHO et al. 2009). Thus, it is observed that the mesoregion of Vale do Rio Doce has no favorable hydric conditions to be out of the acceptable limit of water deficiency (Figure 5). Throughout the extent of the mesoregion, water deficiency ranges from 116 mm (West and South) to 379 mm (Midwest and Northeast), annual amounts considered high for banana production in unirrigated conditions. In this sense, the banana plantation in the mesoregion of Vale do Rio Doce should only be recommended with supplementary irrigation.

Latosolic soils are suitable for banana production to be well-drained, deep (over 100 cm), medium texture to clayish, well-structured, permeable, fertile, neutral to slightly acidic pH, no risk of flooding and salinity free (SALOMÃO; SIQUEIRA, 2015). On the other hand, the shallow, rocky soils, as Neosol and rocky outcrops are inadequate. The mesoregion of Vale do Rio Doce has more than 97% of its area suitable for banana cultivation by having Yellow, Red, Yellow and Red Latosols, Red Yellow Podzolic and Red Nitosol (Figure 6). Only 2.8% of the mesoregion are considered unsuitable for the banana crop, they are Neosol or rocky outcrop, both inapt for culture.

From the suitability maps generated for each variable considered in the study, it was obtained agro-climatic zoning map for the banana in the mesoregion of Vale do Rio Doce (Figure 7). In it you can see that the mesoregion has 28.7% of the area suitable for the cultivation of bananas, since

if practiced with irrigation. This area of 11,000 km² or 1.1 million ha is 27 times larger than the current area planted with banana throughout the state of Minas Gerais. About 71.3% of the area is considered inappropriate to the cultivation of bananas. This is due to the altitude related to the type of mesoregion soil. For this last area, techniques are recommended as liming, fertilization and irrigation (more installments) for inapt soils (Neosol). For restricted soils (Cambisols), besides liming and fertilization is recommended the contour lines and rows of vegetation to allow banana production.

In relation to areas with unsuitable altitudes to banana cultivation (above 900 m) it is recommended the evaluation of the cost-benefit of the use of protected environment for commercial production. Banana growers have available several lines of credit, both for investments in infrastructure as well as for costing of the implanted culture. In some regions of the Canary Islands (Spain) it was observed that the weight of banana bunches increased by 20% under protected cultivation, compared to cultivation in the open sky (GALÁN SAÚCO et al., 1998). Good banana yields are obtained in protected crops also in Morocco (JANICK; AIT-OUBAHOU, 1989). Thus, it is necessary to evaluate whether the increase in productivity with the banana crop in a protected environment justifies the investment made in the activity.

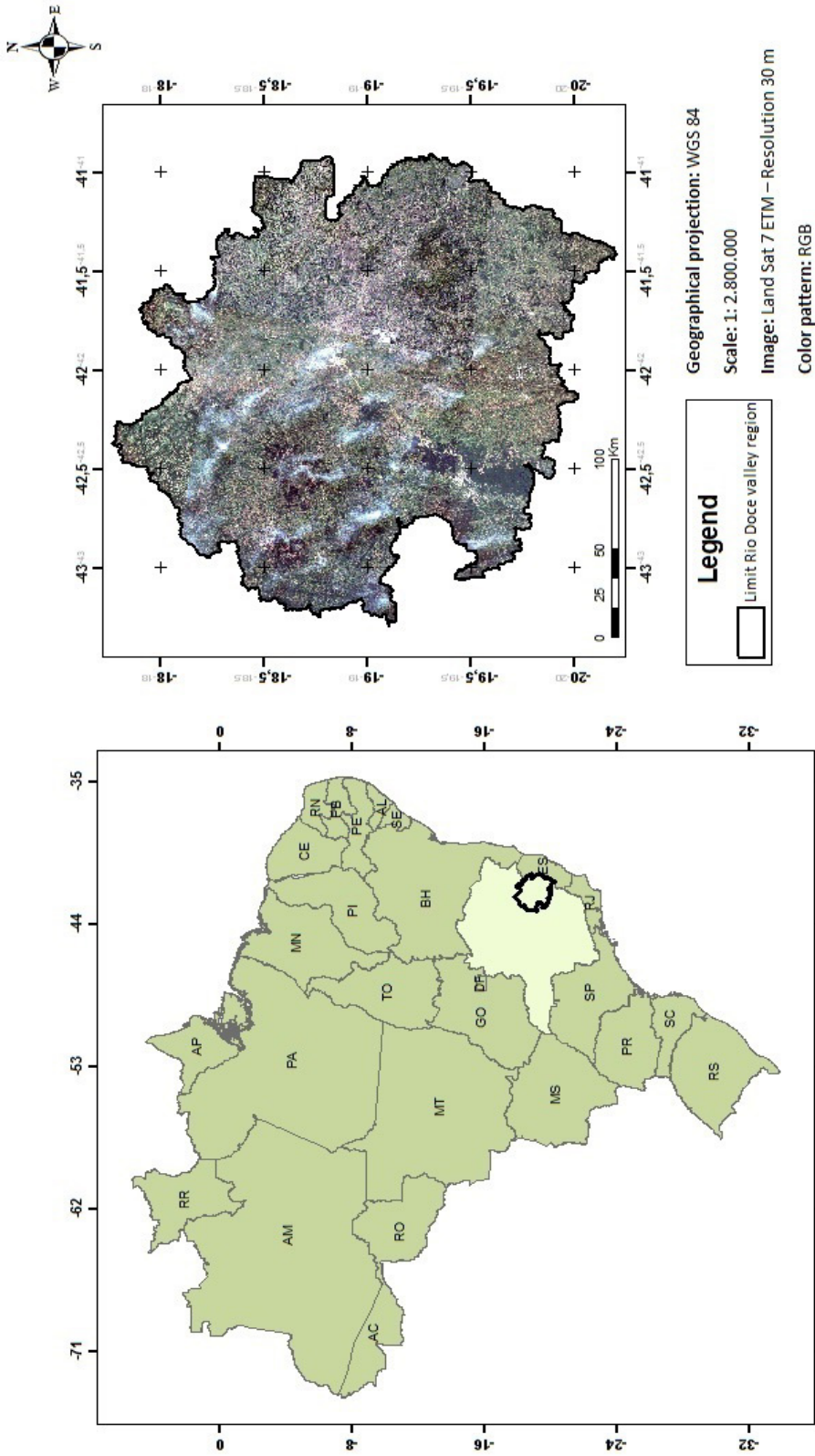


FIGURE 1 – Mosaic Image of Landsat 7 ETM with RGB composition and localization of the study area in relation to Minas Gerais.

TABLE 1 - Classes of aptitude for banana cultivation.

Classes of Aptitude	Annual average temperature (°C)	Annual water deficiency (mm)	Annual average rainfall (mm)	Altitude (m)	Soils
Preferential	28	<100	1900	0 - 300	I
Suitable	18 - 35	<100	1200 - 1900	0 - 900	II
Suitable with irrigation	18 - 35	>100	<1200	0 - 900	II
Suitable with soil management	18 - 35	<100	1200 - 1900	0 - 900	III
Restricted by altitude	18 - 35	<100	1200 - 1900	>900	II
Restricted by soil	18 - 35	<100	1200 - 1900	0 - 900	IV
Inept	<15 e >35	>100	<1200	>900	IV

TABLE 2 – Classes of soil aptitude for banana cultivation.

Group	Classes of Aptitude	Soils
I	Preferred soils	Oxisol Eutroferic and Eutrophic Red Yellow Eutrophic Alfisol, Luvisol Haplic, Cambisol, Chernossolos and Fluvic Neossols Eutrophic, non-salty, non-sodic and well drained.
II	Suitable soils	Rhodic Eutrophic Red Yellow Eutrophic Alfisol, Luvisol Haplic, Cambisol, Chernosol Argilúvico and Neosol Fluvic Eutrophic, non-salty, non-sodic and well drained, Distroferic Red Latosol and dystrophic Red Yellow Latosol and Yellow, Red Nitosol Dystroferic Ultisol dystrophic and Yellow, Cambisol, Vertisol, Chernosol Argilúvico, Fluvic Neossols Dystrophic and or poorly drained, Gleysol, Organosols and Vertisols.
III	Restricted soils	Quartzarenic Neosols Yellow Dystrophic Red Latosol (medium texture) and Iron Quadrangle, Luvisol and Argisol shallow, Chernosol Rêndzico, Luvisol Chromic shallow Orthic, shallow Cambisol, Neosol, Spodosol and some Planosols with thick surface horizons (over 50 cm).
IV	Inapt soil	Litholic Neosols, Argissolos shallow and / or stony, Cambisol shallow and / or stony, Luvisol Chromic Orthic shallow, Planosol and Gleysol.

Source: Adapted from EMBRAPA (2006).

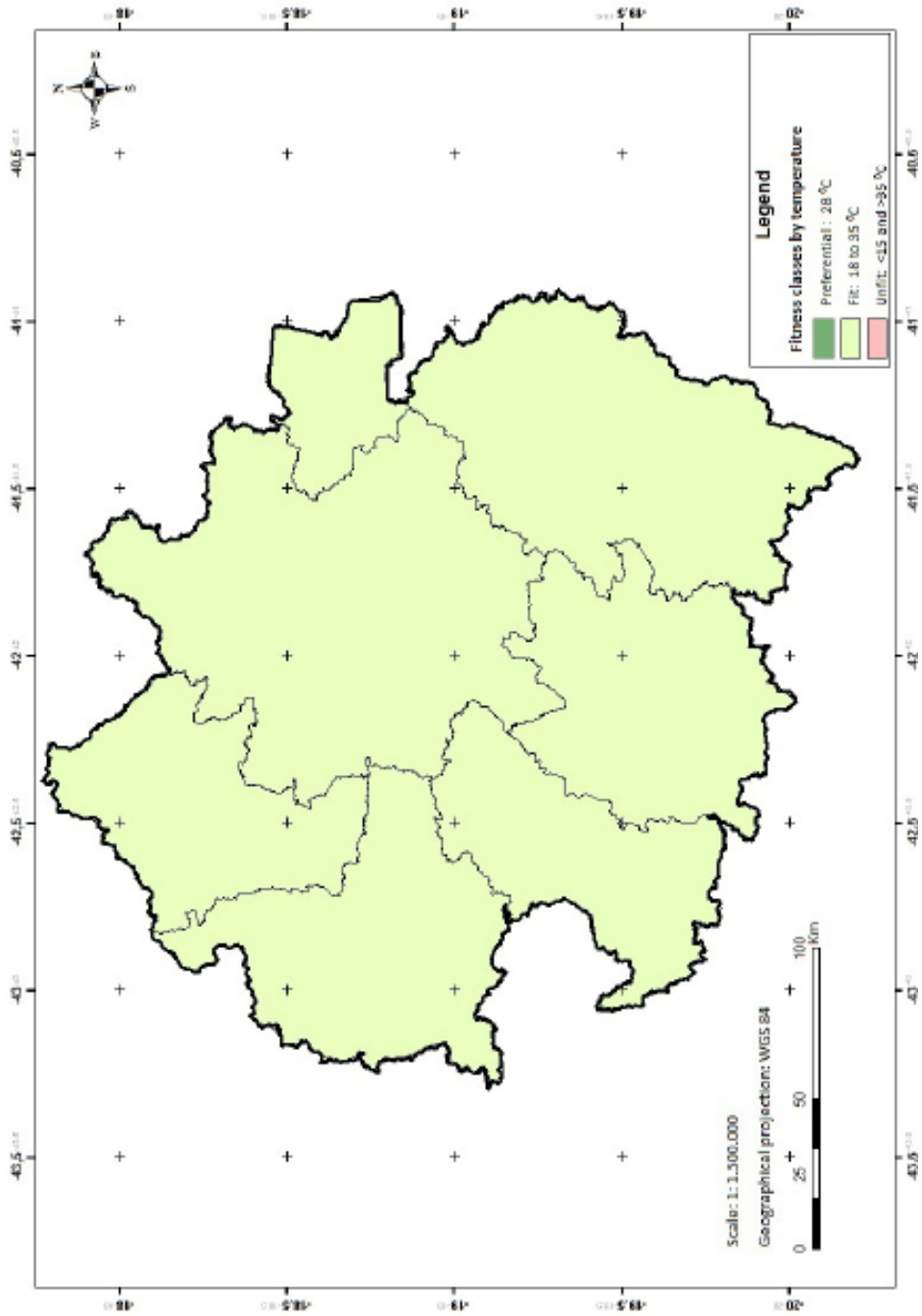


FIGURE 2 – Annual average temperature zones for the cultivation of banana in the mesoregion of Vale do Rio Doce.

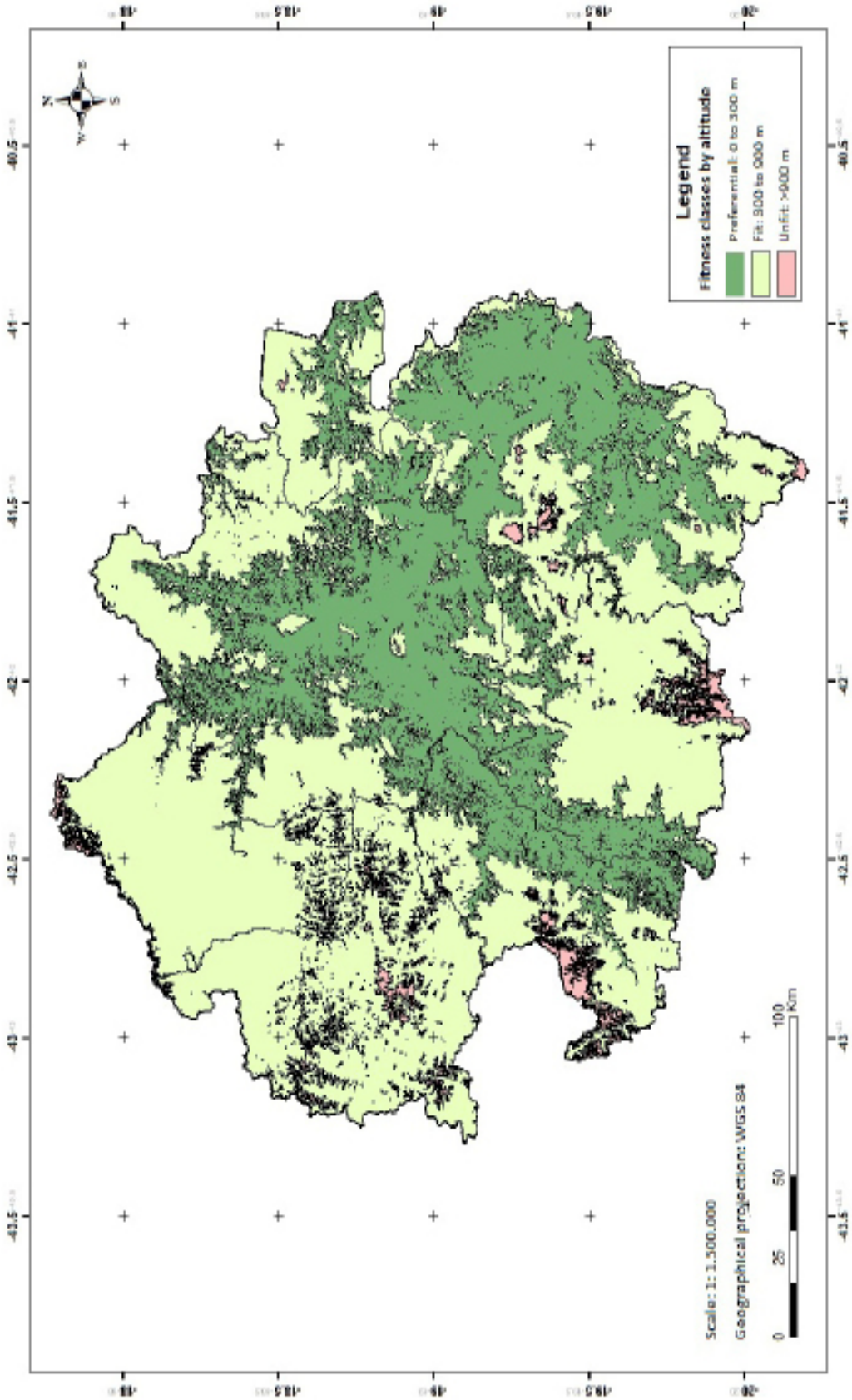


FIGURE 3 – Altitude zones for the cultivation of banana in the mesoregion of Vale do Rio Doce.

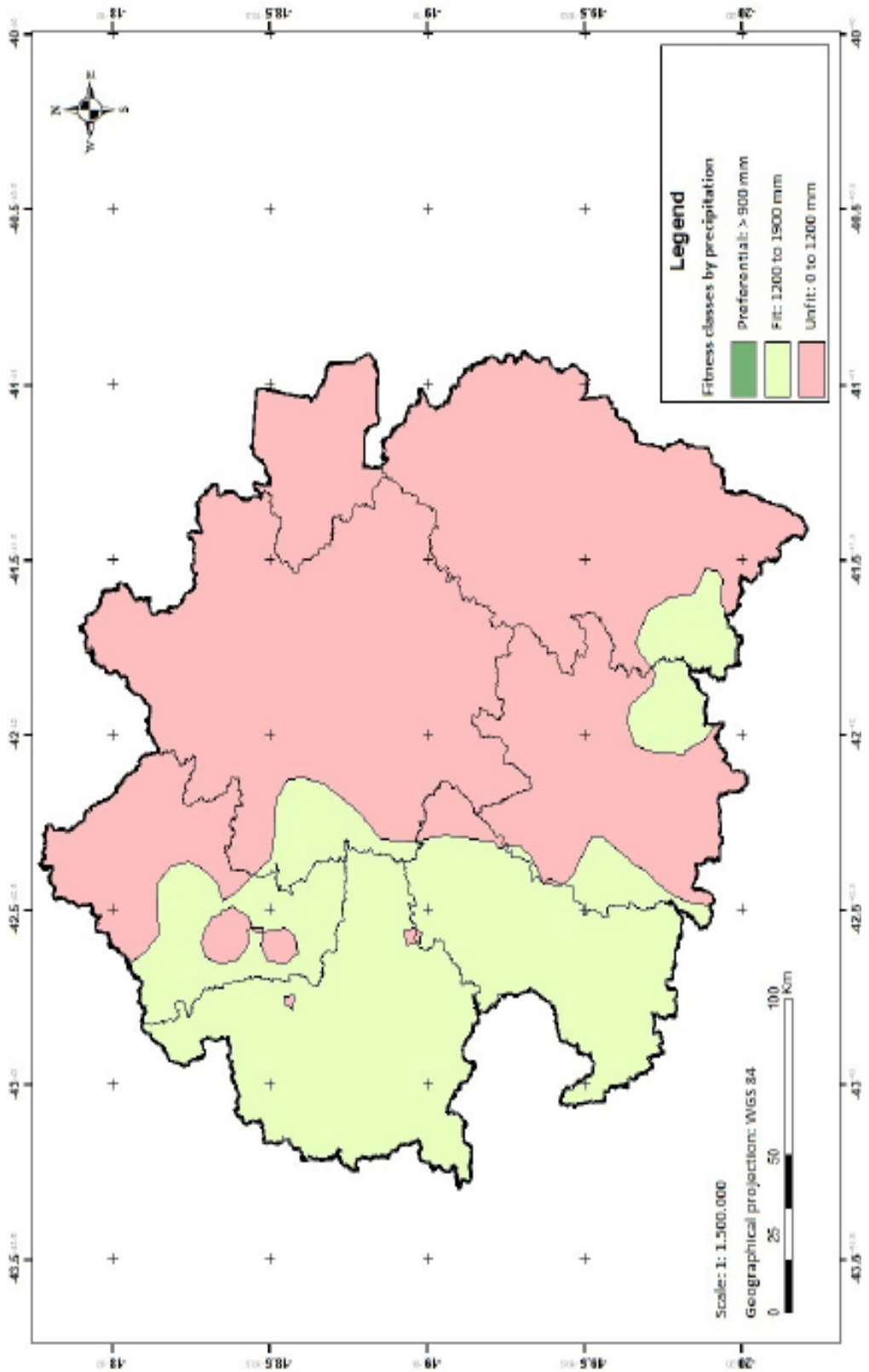


FIGURE 4 – Rainfall zones for the cultivation of banana in the mesoregion of Vale do Rio Doce.

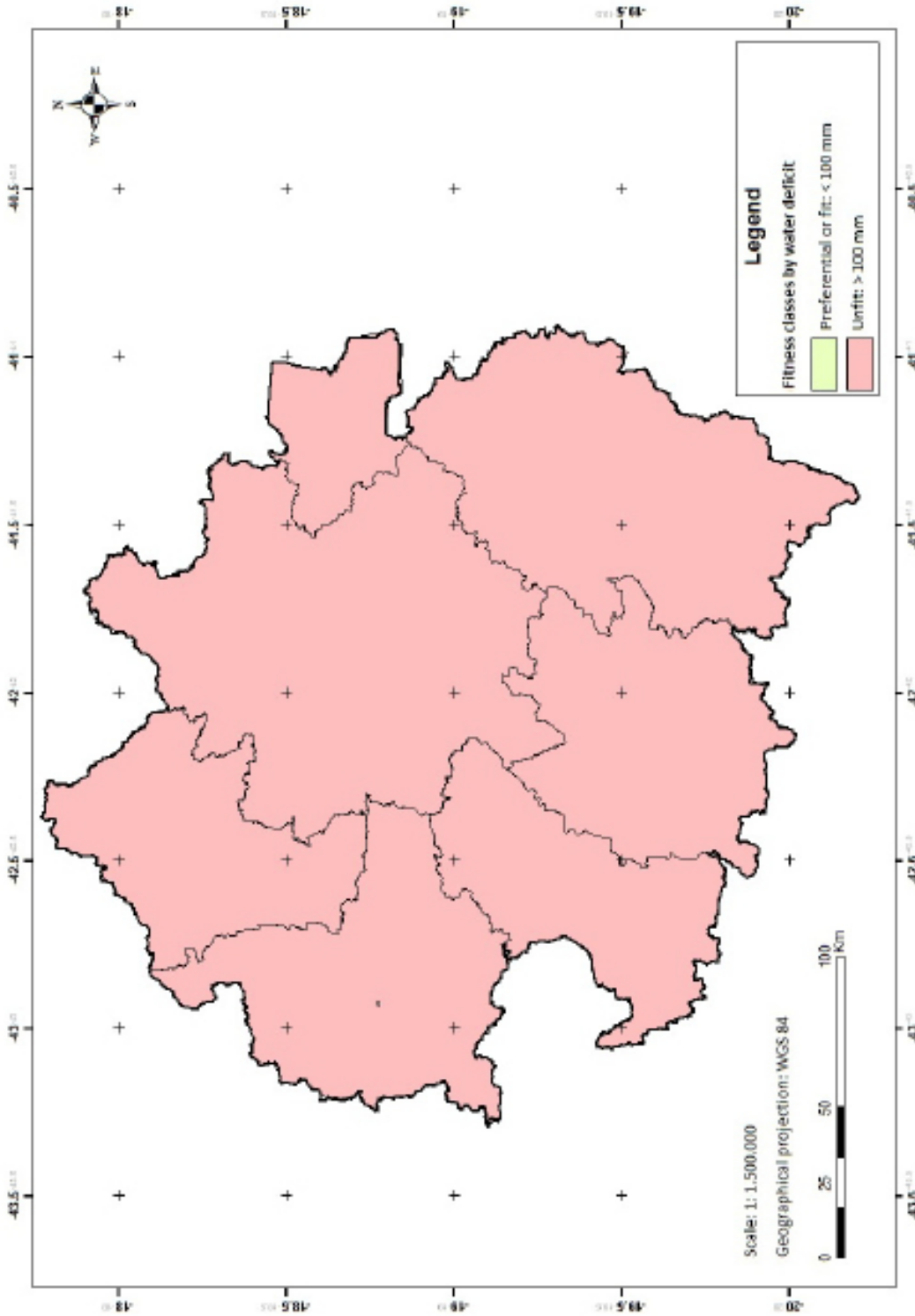


FIGURE 5- Water deficit zones for the cultivation of banana in the mesoregion of Vale do Rio Doce.

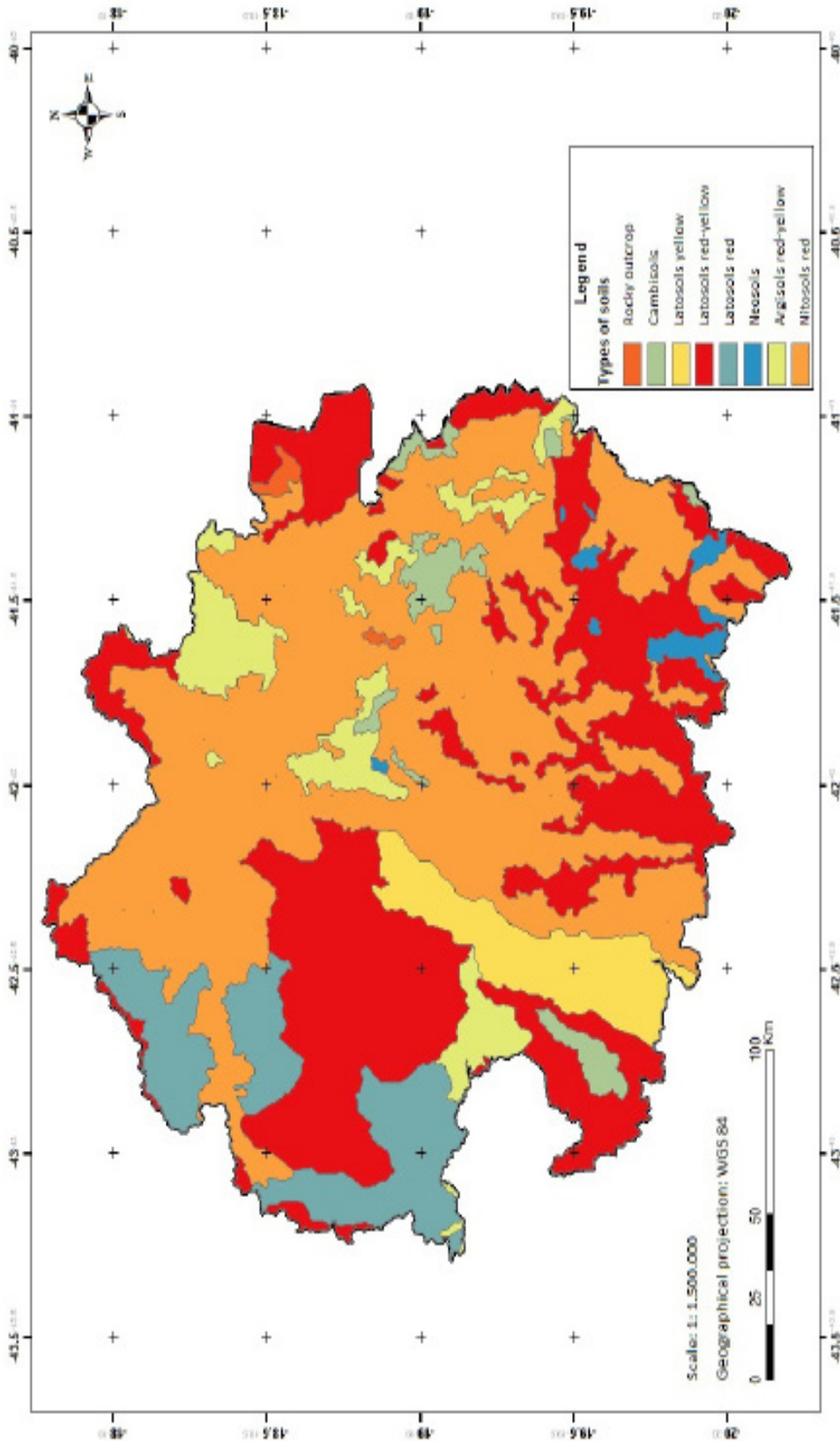


FIGURE 6 - Soil zones for banana cultivation in the mesoregion of Vale do Rio Doce.

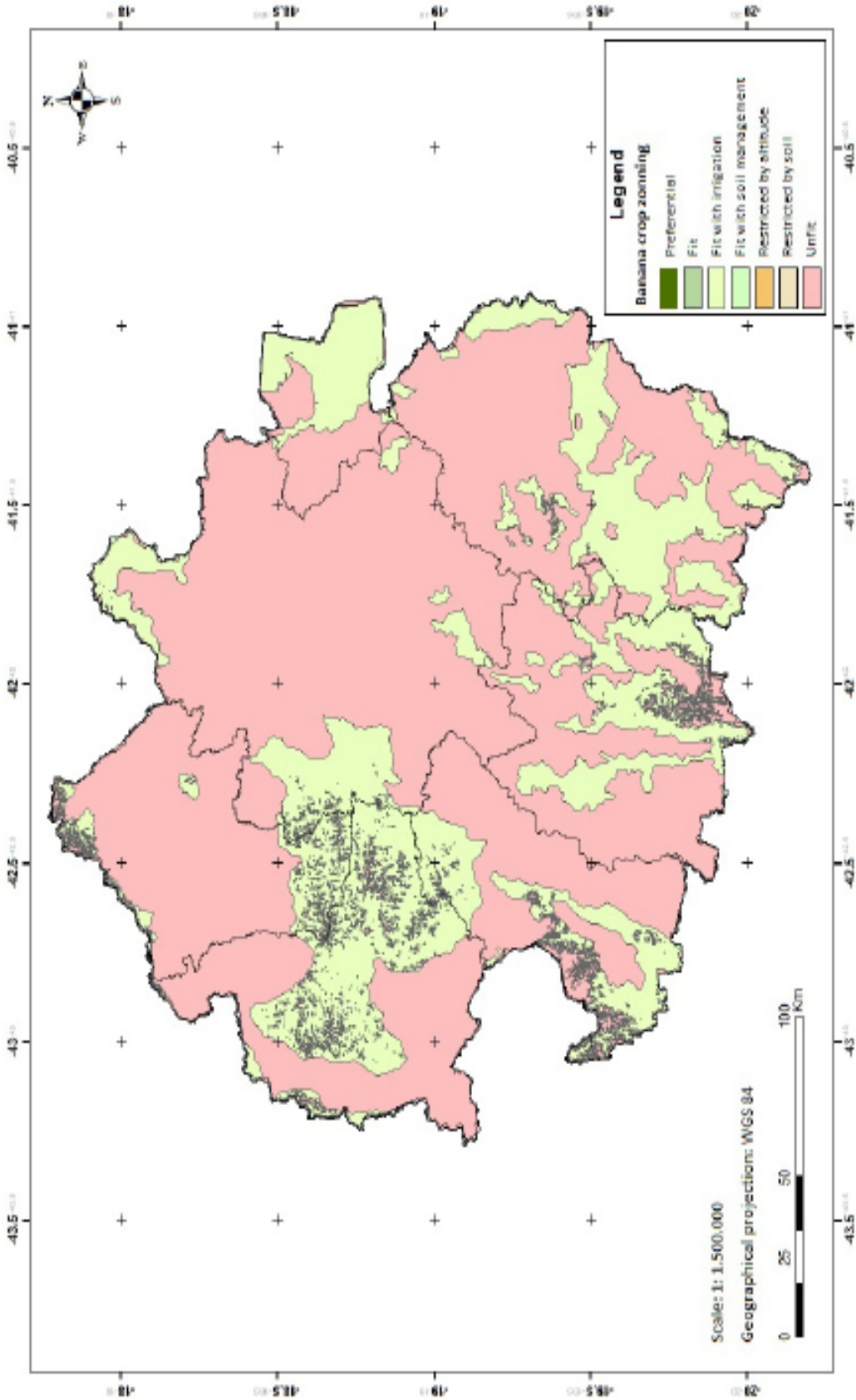


FIGURE 7 - Agro-climatic zoning for banana cultivation in the mesoregion of Vale do Rio Doce.

CONCLUSION

The agro-climatic zoning for banana plants in the mesoregion of Vale do Rio Doce has allowed the conclusion that 28.7% of the area comprising the micro-regions of Guanhães, Mantena and Aimorés, has favorable conditions for irrigated cultivation.

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