XXIII International Cartography Conference

4-10 August Moscow, 2007

Mapping spatial and temporal potassium variability to optimize the agricultural fertilizers application in the SW Goias – Brazil

* DSc. Rachel Bardy Prado – rachel@cnps.embrapa.br (EMBRAPA SOILS Researcher – Rio de Janeiro – Brazil)
DSc. Vinicius de Melo Benites – vinicius@cnps.embrapa.br (EMBRAPA SOILS Researcher – Rio de Janeiro – Brazil)
DSc. José Carlos Polidoro – polidoro@cnps.embrapa.br (EMBRAPA SOILS Researcher – Rio de Janeiro – Brazil)
DSc. Alexey Naumov – alnaumov@geogr.msu.ru (International Potash Institute and Moscow State University – Russia)
DSc. Carlos Cesar Evangelista de Menezes – carlosmenezes@comigo.com.br (COMIGO – Rio Verde – Brazil)
Carlos Eduardo Gonçalves Ferreira - carlosed.gf@hotmail.com (EMBRAPA SOILS Trainee – Rio de Janeiro – RJ).

Abstract

Brazilian soils are very contrasting in relation to fertility and the main soil classes have low levels of K. Agricultural activities, mainly grains production in Brazilian Cerrado, demand high amounts of K. The most K fertilizers are imported playing important role in crop production costs. Although is common the inadequate use of K fertilizers that may result in this nutrient loss. Thus, since 2001 Embrapa and the International Potash Institute (IPI) have kept collaboration to study K behavior to optimize potassium application in Brazil. It is necessary to identify regions with different K levels whose variability may occur in spatial and temporal scales. In addiction, a regional agricultural development planning should built and publish a database that integrate environmental and social-economic data. In this way, the purpose this study was to map spatial and temporal K variability by municipality of southwest Goias, Brazil, from 2003 to 2005. The soil K availability was obtained from database COMIGO Cooperative composed by approximated 10,000 soil fertility analysis at year. The K output by crops was calculated from agricultural census data. First of all, consistence analysis was applied in database to eliminate outliers. After that, descriptive statistic was performed to soil K availability. The ARCGIS 9.1 tools were used to associate values obtained to mapping units (municipality) getting soil K availability and K output maps. Algebra tools were used to overlay these maps to get the K balance map by municipality of SW Goias, Brazil.

Rua Jardim Botânico, 1024, Jardim Botânico, Rio de Janeiro, Brazil, CEP:22460-000

The results showed that spatial and temporal K variability by municipality occur due to different soil properties, different crops and agricultural economy situation that determine the K amount that should be applied. Once tested and consolidated, this methodology may be used to map other major nutrients of the Brazilian agriculture such as phosphorus, magnesium and calcium. Thus, the intention is to generate and provide information to agricultural institutes and universities, but mainly, to provide technical information applied to sustainable agriculture.
Key words: Potassium, K availability, K output, K balance, geothecnologies, digital mapping.

1.0 Introduction

In 2005, Embrapa Soils and the International Potash Institute (IPI) started collaboration to organize soil data for mapping the plant potassium availability found in several soil surveys of the National Soil Archives of Embrapa Soils. The basic motivation was the need for optimum regional distribution of K fertilizers in Brazil, which are mostly imported. Optimized fertilizer distribution would help fertilizer delivery to farmers at lower costs than usual. Presently, up to 40% of the total production cost of grain crops is due to mineral fertilizer (Bernardi *et al.*, 2002). Brazilian farmers receive no governmental subsidies and the prices of mineral fertilizers inhibit them to apply adequate amounts of fertilizer.

Since 1990s, the consumption of potassium fertilizer has been the largest in Brazil, and the recent growthy of agribusiness have promoted potassium fertilizer use, particularly in the Cerrado region (Mascarenhas *et al.*, 2002).

One of the main reasons for the change in agricultural production is the change in the eating habits of consumers combined with environmentally friendly technologies because of social and environmental concerns (Poulisse, 2003). This, in turn, demands the use of environmentally sound techniques to promote food security with simultaneous low environmental impact (Sanchez, 1997).

The use of some geotechnologies tools in scientific studies may help transformations in agriculture. Reliable data acquisition, organization in a georreferenced database and mapping are efficient tools in the changing process. Plant nutrient mapping has been used at the farm level as part of precision agriculture (Bernardi *et al.*, 2002). However, a regional approach is often needed for both governmental and private purposes.

Nevertheless, available data on soil fertility measurements are sparse and collected at different scales in Brazil, associated to soil profiles. Then, the soil profiles data are not representative for all brazilian biomes (Figure 1). In addition the interpolation is often impeded because of unreliable georreferencing. For this, the purpose of this paper was to map K spatial and temporal potassium variability by municipality of SW Goias – Brazil (from 2003 to 2006). There, the farmers are organized in a large cooperative (COMIGO) in which a soil lab produces 10,000 soil analyses, yearly, that allowed this K mapping.

The objective to map soil fertility in regional scale is to contribute to the efficiency of the fertilizer application and the reduction of the production cost.

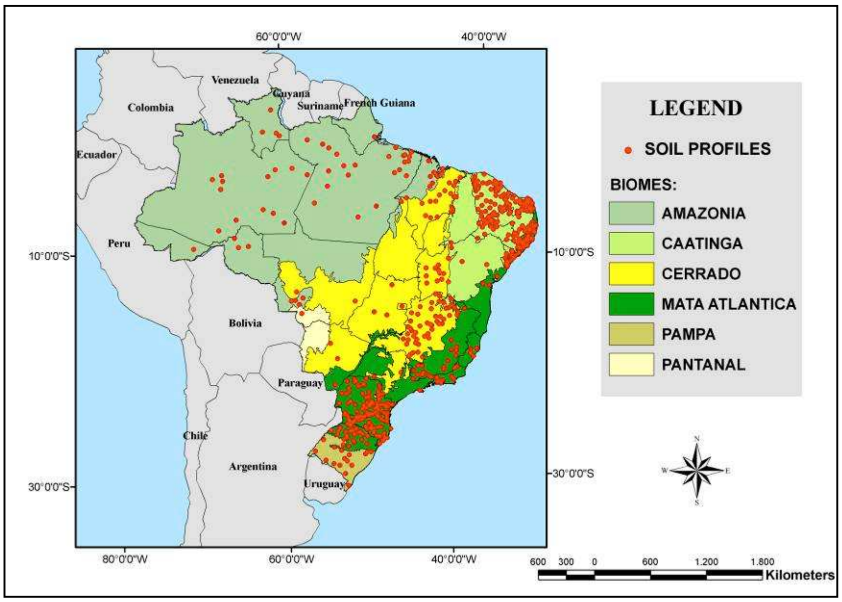

Figure 1: Brazil’s biomes map at 1:5,000,000 scale and soil profiles distribution.

2.0 Study Area

SW Goias is located between 14º09’S e 19º27’S e 48º31’W e 53º12’W geographic coordinates. This area comprises approximately 10 million ha inserted mainly in Cerrado biome – Brazilian Savanna) (Figure 2). The greater part of Cerrado, recovered by natural vegetation, was replaced by agriculture. The rural properties have approximately 800 ha and the land use/land cover pattern is presented in Figure 3. It is an important economic region producing the most quantity of grains of Brazil to serve national and international demands.

In grains tillage agricultural systems, there are basically two kinds of producers: one of them uses low fertilizer levels which limit production and exhaust the soil, and the other uses high fertilizer levels which generally cause loss by leaching and volatilization. The leaf analysis is not very common, in spite of helping the application of fertilizers.

Other serious problem in most agricultural systems in Brazil is that producers use commercial proportion recommendations that are not adapted to region conditions. In SW Goias, for example, it is common to use 400 kg of 2-20-18 in soybean crops. In this region, the argissolos present a high K level, and they don't require an application of 72 kg of K_2O by ha. In addition, the excess of K in sandy soils might cause salinization of the radicle system and K loss by leaching because of the high level of solubility. In this situation, the excess of K has been lost but its cost is high and this fertilizer is imported from other countries.

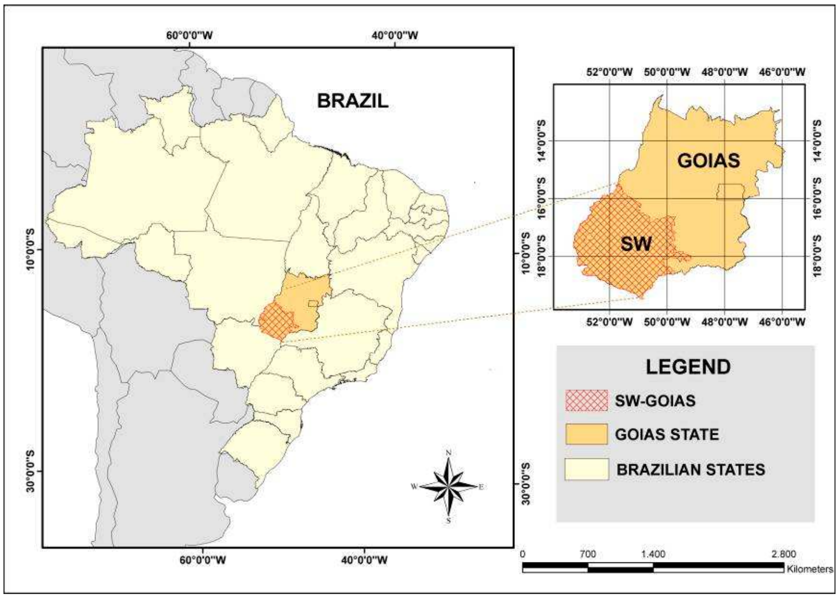

Figure 2: Study area localization map.

3.0 Material and Methods

The cartographic projection adopted in this mapping was Universal Transverse Mercator (UTM) and WGS84 datum. The mapping units were the municipalities of SW Goias, obtained from IBGE (2001).

3.1 Soil potassium availability

The soil K availability data were obtained from COMIGO soil data set. This cooperative takes about 10,000 soil samples, yearly. At first, the consistence analysis of data was done and outliers were deleted. After the elimination of outliers, the statistic analysis was done for each municipality using the soil data set from 2003 to 2006 using a statistical software. It is important to mention that the sample number is different for each municipality; for example, for Perolândia, there are 2 associated samples and for Rio

Verde there are 8.487. But for the temporal K availability analysis only municipalities whose soil data set was higher than 50 were considered.

SW Goias has 86 municipalities associated with COMIGO. But, in this step, only 51 of them were mapped because the others did not have K information. Four classes of interpretation of soil K were used to map K availability, as suggested by Raij (1985). Besides, one more class was associated with no data related to municipalities without associated soil K:

No data – municipalities without associated soil K

0-30 mg kg^{-1} soil – too low

30-60 mg kg^{-1} soil - low

60-120 mg kg^{-1} soil - medium

120-240 mg kg^{-1} soil – high

3.2 Potassium output

The K average level outputs (kg/ha) for thirteen crops from this region were obtained from Yamada and Lopes (1999). This information multiplied by municipality agricultural productivity (t/ha) (IBGE, 2003) allows us to estimate the K output of SW Goias from 2003 to 2006. The crops considered were: rice, cotton, coffee, sugar cane, lemon, orange, bean, soybean, corn, tomato, peanut, manioc and wheat. Based on these results, the 2003-2006 K average output map was done for 51 municipalities of SW Goias. Five classes with equal intervals were used in K output maps: 0-150, 150-300, 300-450, 450-600 and >600 $kg.ha^{-1}$.

For temporal K output analysis, only municipalities whose soil data set was higher than 50 were considered. To map both soil potassium availability and output, the table comprising the results associated with municipalities (dbf format) was exported to ARCGIS9.1. It allowed the K availability and output spatialization.

3.3 Potassium balance

The K average availability unit ($mg.kg^{-1}$) was converted to the same unit of K average output ($kg.ha^{-1}$). After that, both maps were converted from vector to raster format and overlaid using Raster Calculator tool of ARCGIS 9.1 to obtain the K balance map ($mg.ha^{-1}$). In this process was subtracted the K average output values from K average availability.

3.4 Textural soil classification

At first, a textural soil classification was applied considering sand, clay and silt average percentage for each SW Goias municipality (EMBRAPA, 2006). In this step, COMIGO soil data set was used. These data are very important; they help the discussion about K recommendation because the soil texture can influence K loss by leaching. After that, the soil texture map was obtained by ArcGIS 9.1 for 51 municipalities of SW Goias.

4.0 Results and discussion

4.1 Spatial K variability

Figure 3 shows the spatial variability of K average availability for municipality. The municipalities 45, 52 and 56 presented too high K level because in this region predominated the cotton crop until 90's. And this crop needs high level of K application. Comparing the Figure 3 and 4 is possible observe that the high and medium classes in K average availability map are coincident to clay soils. These kinds of soils keep more K available than sandy soils and there is not large loss by leaching. On the other hand, the low and too low classes are coincident to sandy soils. In these kinds of soils the loss by leaching is more common due to K solubility.

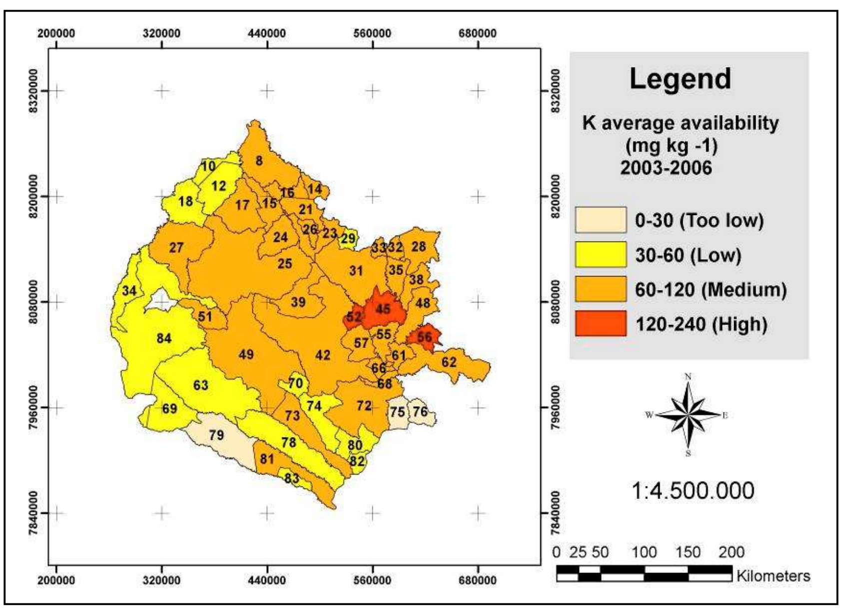

Figure 3: K average availability map from 2003 to 2006 by municipality.

Figure 5 shows that the spatial variability of K average output doesn't correspond, exactly, to K average availability distribution. The high output classes are related to the municipalities with greater productivity (mainly soybean), for example, the 28, 31, 42, 62 (450-600 $kg.ha^{-1}$) and 32, 38, 45, 56, 57 (300-450 $kg.ha^{-1}$). Nevertheless, the K level decreases from east to west for both K average availability and output maps (Figure 3 and 5) due to different kinds of soil.

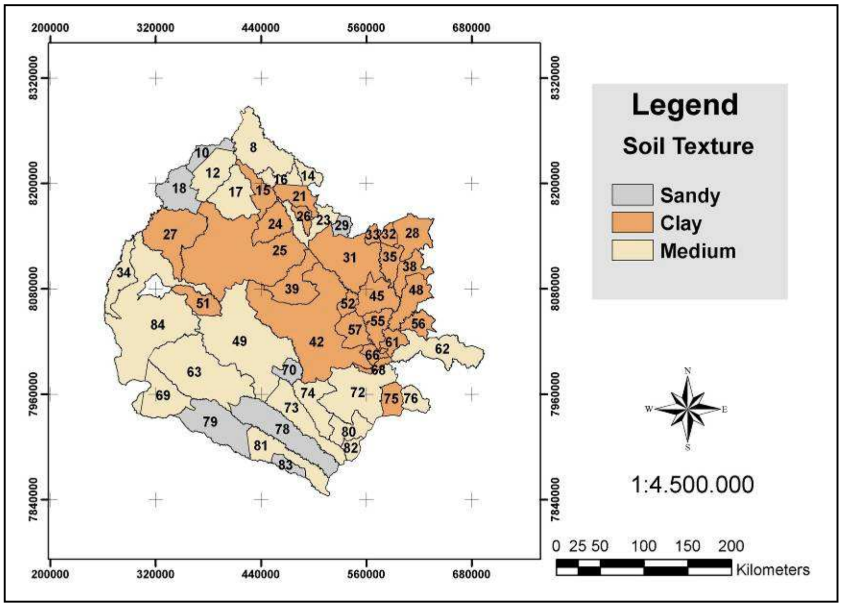

Figure 4: Textural soil groups map by municipality.

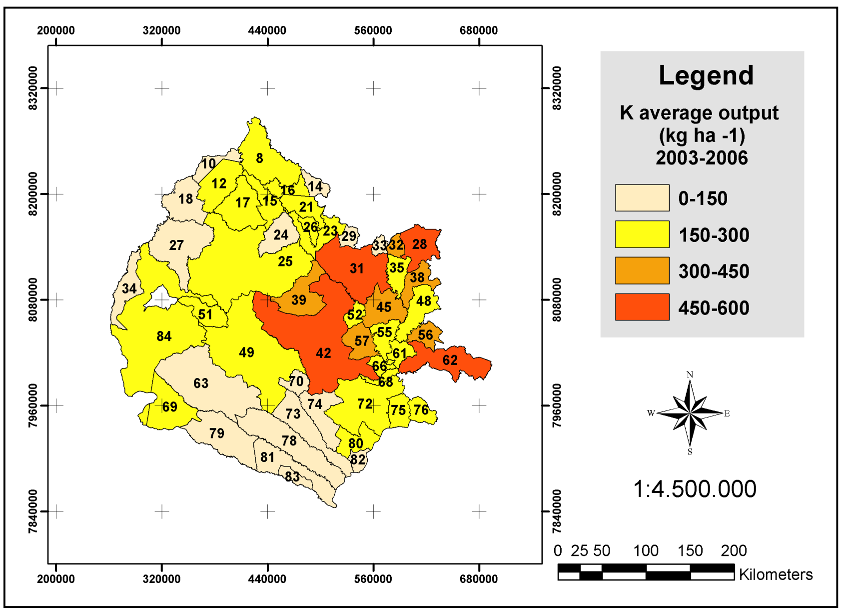

Figure 5: K average output map from 2003 to 2006 by municipality.

These results presented that the K availability and output spatial variability should be considered in the K recommendation considering the regional scale to otimize financial and natural resources.

4.2 Temporal K variability

Figure 6 shows the temporal K availability map by municipality in 2003, 2004, 2005 and 2006. It is observed that the soil K availability increased from 2003 to 2005, after that its level decreased until 2006. This fact occurred due to economical processes like the soybean price that kept high from 2003 to 2005 and lower in 2006. For this, more quantity of K was applied when the soybean price was high, decreasing in 2006. Consequently, the K availability in soil reduced, too.

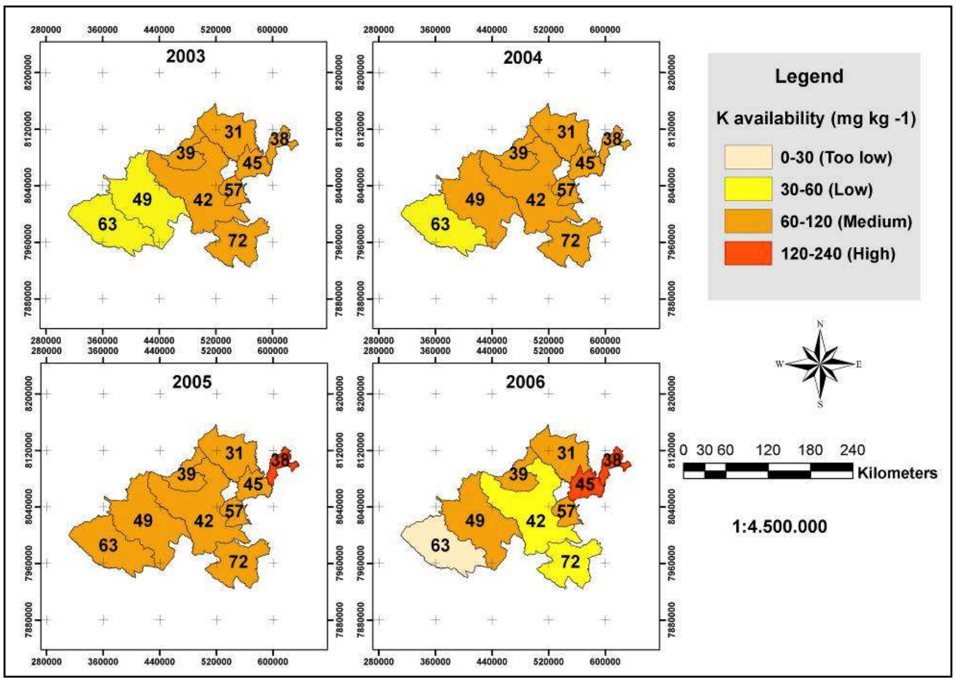

Figure 6: Temporal K availability maps by municipality.

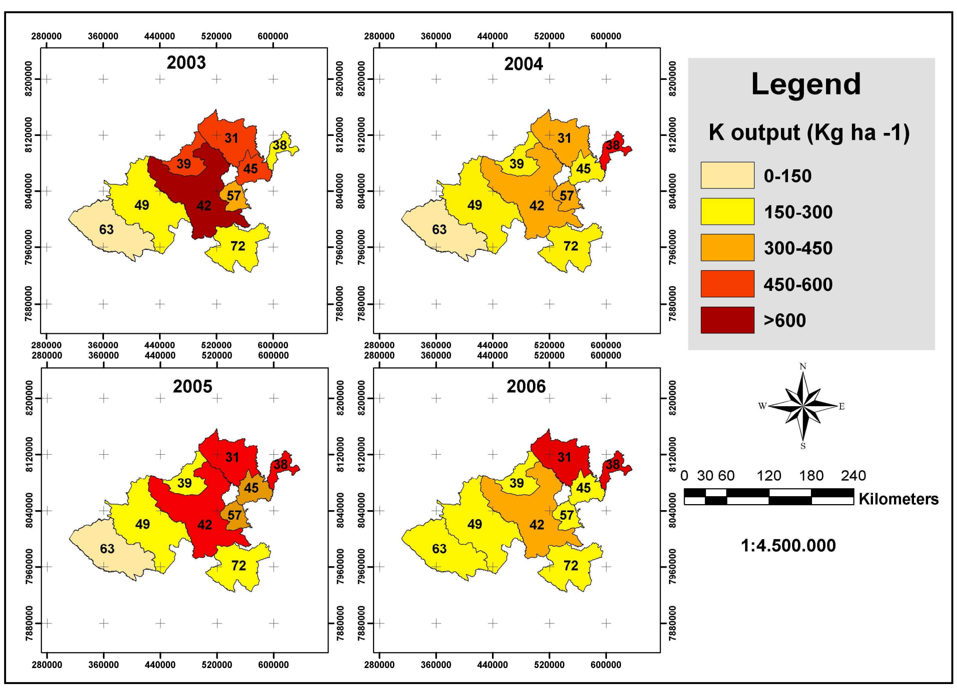

Figure 7: Temporal K output maps by municipality.

Figure 7 shows the temporal K output map by municipality in 2003, 2004, 2005 and 2006. The greater K output levels occurred in 2003 (above 400 kg. ha^{-1}), mainly in the municipalities whose soybean productivity was higher, too (31, 39, 42 and 45). In 2004 K output decreased due to natural phenomena like dry season and soybean illness. But in 2005 the K output increased again. K output decreased From 2005 to 2006. It is explained by K application reduction due to low price of the soybean.

4.3 K balance

K balance map obtained from availability and output maps has six classes, three related to negative balance (-250 to – 100, -100 to – 50 and -50 to 0 kg. ha^{-1}) and three related to positive balance (0 to 50, 50 to 100 and 100 to 250 kg. ha^{-1}) (Figure 8). 50 kg de K is, approximately, the K fertilizers amount applied in a soybean cycle. Then, a deficit of 50 kg of K for ha correspond to a harvest without application of K fertilizers. In this case, probably, the productivity will decrease in the next harvest. On the other hand, the municipalities that presented positive K balance, they should reduce the K fertilizers application in the next crop cycle, without reduce the productivity. The ideal situation should be all municipalities presenting K balance near to zero.

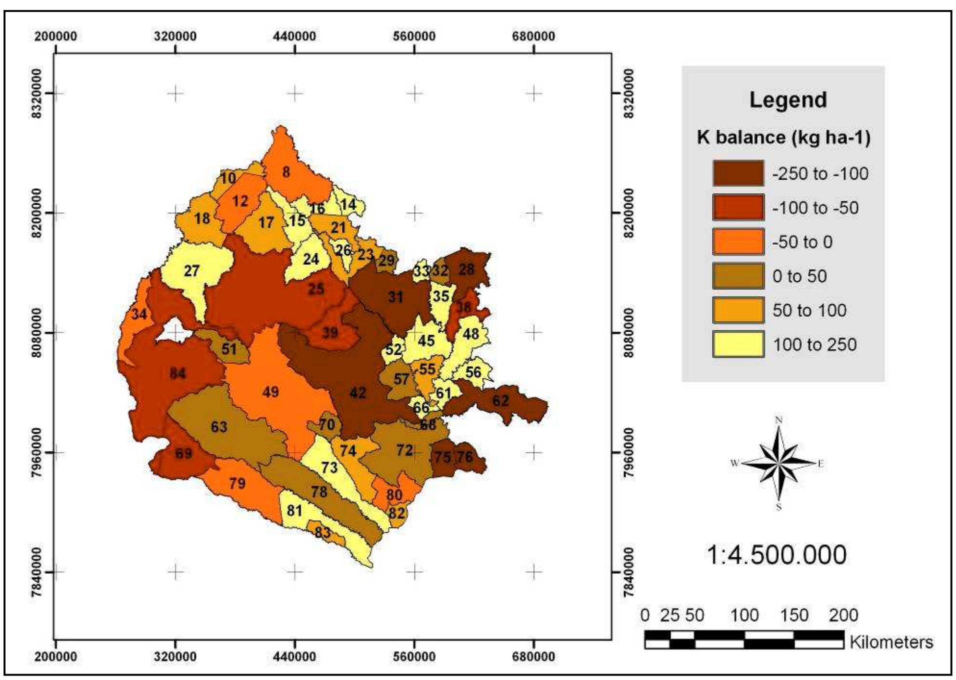

Figure 8: K balance map by municipality.

5.0 Conclusions

The results showed the importance to consider, in fertlizer recommendation, not only the different soil characteristics and spatial K variability, but the temporal variability that is influenced by economical and natural aspects. The monitoring of soil fertility in spatial and temporal level should occur not only in municipality scale but in farm leavel. For this, is necessary to organize a data base with soil fertility information, yearly. Thus, geoprocessing tools can be used to otimize the fertilizers application planning.

Acknowledgment

This work was financially supported by the International Potash Institute (IPI). The Soil Database was supplied by COMIGO-Rio Verde (Goias).

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