II Pedometrics
Nov, 24th to 27th, 2021
Brazil

Soil evaluation and socioeconomic factors influence on agricultural efficiency: a pilot study in Rio de Janeiro

GOMES, Eliane[1]; FIDALGO, Elaine Cristina[2]; OLIVEIRA, Elton[3]; MARTINS, Alba Leonor[4]; OLIVEIRA, Aline[5]; COELHO, Maurício[6]
[1] Embrapa / SIRE, eliane.gomes@embrapa.br; [2] Embrapa Solos, elaine.fidalgo@embrapa.br; [3] Universidade Federal Fluminense, oliveruff2@gmail.com; [4] Embrapa Solos, alba.leonor@embrapa.br; [5] Embrapa Solos, aline.oliveira@embrapa.br; [6] Embrapa Solos, mauricio.coelho@embrapa.br

Thematic Session: 02: Legacy data: How turn it useful?

Abstract
In this paper we evaluate the agricultural efficiency of the municipalities of the state Rio de Janeiro and assess the influence of contextual variables on the performance. The scores are computed by means of Data Envelopment Analysis (DEA) models, where inputs are land, labor and capital (or technology), and the value of crops and of livestock productions are the outputs. Covariates are related to soil evaluation (susceptibility to erosion and land use suitability) and to socioeconomic factors. The results show that high levels of susceptibility to erosion influence negatively and significantly the efficiency scores. The land suitability to agriculture and the land suitability to livestock are positively associated with performance. The presence of family-based farmers favors the agricultural performance of the assessed municipalities.
Keywords: Agricultural performance; Soil erosion susceptibility; Land use suitability; Data envelopment analysis; Fractional regression.

Introduction

The farming sector in the state of Rio de Janeiro, Brazil, comprises mainly vegetables, fruits and grains productions. Dairy and beef cattle farming are also present in almost all the municipalities. These production chains strengthen the economy in the countryside (employment and income), boost rural communities and play an important role in food and nutritional security for the population of the State (EMATER-RIO, 2017, 2019). They are predominantly performed by family-based farmers (IBGE, 2019).

Given the importance of this activity, here we evaluate the agricultural efficiency of these municipalities by means of Data Envelopment Analysis (DEA) models. Input dimensions are proxies for land, labor and capital. Outputs are defined by the value of agricultural productions. These data were obtained from the 2017 Brazilian agricultural census (IBGE, 2019). In addition, we seek to identify exogenous variables that potentially affect performance. These covariates are variables from the PronaSolos databases, referring to soil evaluation (classes of soil susceptibility to erosion and to the different land use suitability), and socioeconomic factors from the 2017 census.

Methodology

DEA (COOPER et al., 2007) is a mathematical programming approach that computes efficiency scores for a group of observations (so-called DMU). These measures are based on the level of resources used (inputs) and the results obtained (outputs) in a production process. Each individual observation is optimized to estimate a piecewise linear efficient frontier, composed of the best practices from the sample (benchmarks).

Here we assume the variable returns to scale hypothesis (VRS) and output orientation, in accordance with other similar studies, as Souza et al. (2020). The envelope formulation of this DEA model is presented in (1), where h_0 is the efficiency score of DMU 0 under evaluation; x_{ik} is the input *i, i*=1...*r*, of DMU *k, k*= 1...*n;* y_{jk} represents the output *j, j*= 1...*s*, of DMU *k;* x_{io} and y_{jo} are the inputs *i* and the outputs *j* of the DMU 0; λ_k is the contribution of DMU *k* to the target of DMU 0 (benchmarks have non-zero λ_k).

$$
\begin{aligned}
&Max\ h_0\\
&subject\ to\\
&x_{i0}-\sum_k x_{ik}\lambda_k \geq 0, \forall i; \quad -h_0 y_{j0}+\sum_k y_{jk}\lambda_k 0, \forall j; \quad \sum_k \lambda_k = 1; \quad \lambda_k \geq 0, \forall k
\end{aligned}
\tag{1}
$$

We considered three input dimensions: land, labor and capital. Land was defined as the sum of crops, forestry and livestock areas (hectares). Labor was represented by the total expenses on salaries (thousand R$). Capital, or technology, included expenses on different inputs, as services, fertilizers, seeds, pesticides, medicines for animals, salt, feed, transportation, electricity, machinery, fuels, among others (thousand R$). The outputs are the value of crops production (thousand R$) and the value of animal production (thousand R$). This approach allows municipalities with specialized production or with a good combined production arrangement to be efficient, as in Gomes et al. (2009). There were 89 municipalities with valid production data.

Due to the nature of DEA type responses (scores between 0 and 1), Ramalho et al. (2010) proposed fractional regression models to identify covariates that affect DEA scores. Let z_j be the vector of covariates for municipality *j*. A fractional regression assumes $E\left(\hat{h}_n\left(x_j, y_j \middle| z_j\right)\right) = G\left(\delta' z_j\right)$, where *G*(.) is a non-linear function with values in (0,1] and *δ* is a vector of parameters. The model can be estimated by non-linear least squares or quasi-maximal likelihood.

The covariates used in the regression fit were: percentage of areas with susceptibility to erosion (*ps1* = very low; *ps2* = low; *ps3* = moderate; *ps4* = high; *ps5* = very high) (FERRAZ et al., 2021); percentage of areas with regular or restricted suitability for crops (*paplav*); percentage of areas with regular or restricted suitability for pastures and crops (*pappast*); percentage of areas with restricted suitability for forestry or unsuitable (*papoutra*) (CARVALHO FILHO et al., 2003); percentage of family-based farmers (*paf*); percentage of farmers that received technical assistance (*pat*); percentage of farmers that received credit/financing (*pfin*) (IBGE, 2019).

Results and discussion

Figure 1 shows the distribution of the efficiency scores. The average efficiency was 55.1%. This non-homogeneity in performance agrees with Souza (2019), regarding rural development in the State.

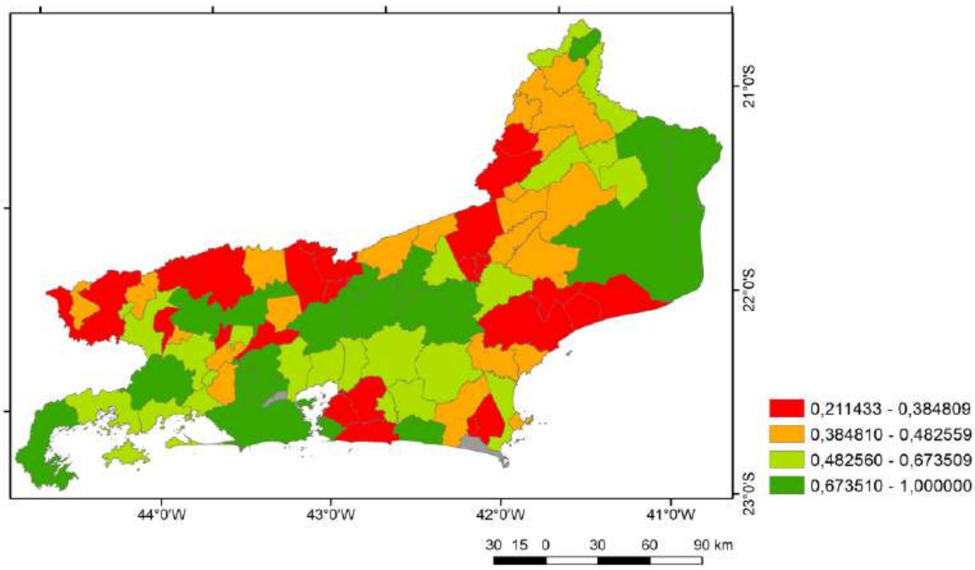

Figure 1: Geographical distribution of the DEA efficiency scores in Rio de Janeiro.

In Table 1 we can see the fractional regression fit. *pat* and *pfin* were not significant and were dropped from the model. Correlation between observed and predicted values is 72.1%. Municipalities with higher proportion of family-based farms are more efficient. The higher are the percentages of areas with moderate, high and very high susceptibility to erosion, the lower are the efficiency scores. Suitability to crops affects positively the efficiency. Suitability to livestock and crops has marginal positive effect.

Table 1: Fractional regression fit. Covariates were measured in log scale.

	Coefficient	Standard error	z	P>|z|	95% Confidence interval	
paf	1.235	0.342	3.61	0.000	0.565	1.904
ps1	0.020	0.100	0.20	0.843	-0.175	0.215
ps2	-0.247	0.204	-1.21	0.225	-0.647	0.152
ps3	-0.797	0.280	-2.85	0.004	-1.346	-0.248
ps4	-0.343	0.096	-3.58	0.000	-0.530	-0.155
ps5	-0.433	0.186	-2.33	0.020	-0.797	-0.068
paplav	0.167	0.063	2.65	0.008	0.044	0.291
pappast	0.364	0.224	1.62	0.105	-0.076	0.804
papoutra	-0.045	0.095	-0.48	0.633	-0.231	0.140
constant	-1.552	1.690	-0.92	0.359	-4.864	1.761

Conclusions

The agricultural economic activity in the state of Rio de Janeiro has a medium overall performance. Soil evaluation factors are influential: moderate and higher levels of susceptibility to erosion affect significantly and negatively the performance; suitability to crops and to livestock productions have a positive association with performance. The presence of family-based production is also positive. These results may support (i) public policies related to soil governance (e.g., PronaSolos and the National Policy for Soil and Water Conservation in Rural Environments), and (ii) the achievement of international agendas commitments at a national level, such as the Sustainable Development Goals (e.g., SDG 2) and the Global Soil Partnership.

References

CARVALHO FILHO, A.; LUMBRERAS, J.F.; AMARAL, F.C.S.; NAIME, U.J.; SANTOS, R.D. dos; CALDERANO FILHO, B.; LEMOS, A.L.; OLIVEIRA, R.P.; AGLIO, M.L.D. **Avaliação da aptidão agrícola das terras do Estado do Rio de Janeiro.** Rio de Janeiro: Embrapa Solos, 2003. 32 p. (Boletim de Pesquisa e Desenvolvimento, 30).

COOPER, W.; SEIFORD, L.M.; TONE, K. **Data Envelopment Analysis: a comprehensive text with models, applications, references and DEA-Solver software**. New York: Springer, 2007. 489p.

FERRAZ, RPD; SIMÕES, M.; LUMBRERAS, J.F.; COELHO, M.R.; BACA, J.M.; FREITAS, P.L.;LIMA, E.P.; KUCHLER, P.C.; ALMEIDA, M.B.F. **Mapa de suscetibilidade dos solos à erosão hídrica do Brasil (Primeira aproximação)**. Disponível em: http://geoinfo.cnps.embrapa.br/documents/2916. Acesso em: 02 ago. 2021.

EMATER-RIO. **ASPA – Acompanhamento Sistemático da Produção Agrícola** (2019). Disponível em: http://www.emater.rj.gov.br/areaTecnica/cult2018.pdf. Acesso em: 02 ago. 2021.

EMATER-RIO. **Bovinocultura – Pecuária de Leite/Corte** (2017). Disponível em: http://www.emater.rj.gov.br/areaTecnica/RelBovi2017.pdf. Acesso em: 02 ago. 2021.

GOMES, E.G.; GREGO, C.R.; SOARES DE MELLO, J.C.C.B.; VALLADARES, G.S.; MANGABEIRA, J.A.C.; MIRANDA, E.E. Dependência espacial da eficiência do uso da terra em assentamento rural na Amazônia. **Produção**, v. 19, p. 417–432, 2009.

IBGE. Instituto Brasileiro de Geografia e Estatística. **Censo Agropecuário 2017** (2019). Disponível em: https://sidra.ibge.gov.br/pesquisa/censo-agropecuario/censo-agropecuario-2017. Acesso em: 19 jul. 2021.

RAMALHO, E.A.; RAMALHO, J.J.S.; HENRIQUES, P.D. Fractional regression models for second stage DEA efficiency analyses. **Journal of Productivity Analysis**, v. 34, p. 239–255, 2010.

SOUZA, G.S.; GOMES, E.G.; ALVES, E.R.A. Two-part. fractional regression model with conditional FDH responses: an application to Brazilian agriculture. **Annals of Operations Research**, 2020. DOI: https://link.springer.com/article/10.1007/s10479-020-03752-z.

SOUZA, R.P. O desenvolvimento rural no Estado do Rio de Janeiro a partir de uma análise multidimensional. **Revista de Economia e Sociologia Rural**, v. 57, n. 1, p. 109–126, 2019.