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Albedo Trend Analyses in Atlantic Forest Biome Areas

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Abstract

The albedo is an important variable that controls the balance of radiation and energy of the atmosphere, so changes in land cover cause alterations in albedo values, influencing changes in climate behavior at different scales. The goal in this work was to investigate the possible occurrence and causes associated with surface albedo trends within the Atlantic Forest biome (São Francisco de Paula, state of Rio Grande do Sul, Brazil), during the last thirty years (1987-2017), evaluating the impacts of the forest cover structure on albedo trends. The study included images of the TM/Landsat 5 and OLI/Landsat 8 sensors over the period 1987 to 2017. The surface albedo was obtained from the SEBAL algorithm, which includes in its variables the reflectance values of each band, reflected solar radiation and atmospheric transmissivity. The trend analysis was performed by the Mann-Kendall test verifying the existence of significant trends over 30 years. Subsequently, the influence of vegetation greenness on the trend presented by the albedo surface was evaluated. Approximately 92% of the pixels with significant tendency are associated with the decreasing tendency of the albedo. The downward trend was observed with the change from the field to the forest cover, while increasing trends were influenced by the change in forest cover, such as the suppression of individuals from the upper forest canopy. The forest populations in areas of the Mata Atlântica biome had a large participation in the energy balance, which exposed a reduction of approximately 60% of the surface albedo with its implantation, showing its importance for reducing the emission of energy to the atmosphere. The spatial pattern of the trend distribution of the surface albedo is related to the concentration and vigor of the arboreal vegetation.

Keywords: Mann-Kendall, National Forest of San Francisco de Paula, index of vegetation

1. Introduction

Issues related to climate change have been a constant theme of international discussions over the last decades in order to establish measures aimed at reducing the emission of pollutant gases as well as finding mitigating measures for this problem (Souza & Azevedo, 2012; Global Climate Change, 2018). In this context, forests are relevant due to their potential for storage and capture of pollutants from the atmosphere, and particularly, for the atmosphere carbon storage and sequestration (Nowak et al., 2013; Ni et al., 2016; Planque et al., 2017). In this sense, the arboreal vegetation is particularly a bond between the flow of the terrestrial surface and the atmosphere. Thus, Davin and Noblet-Ducoudré (2010) consider that changes in vegetation cover can interfere in the cycle of flow changes and, consequently, influence the climate, and a variable closely related to the atmospheric radiation balance corresponds to the albedo (Lukes et al., 2016).

For this reason, the surface albedo is one of the most relevant climatic variables, and changes in this property modify the radiation and energy balance of the surface, which can be detected by monitoring this environmental variable (Silva et al., 2016). Planque et al. (2017) points out that the albedo presented by the forest cover represents an important variable to track changes in vegetation, so that changes in vegetation greenery have been shown to influence the albedo values of the surface (Tian et al., 2014). Thus, the Normalized Difference Vegetation Index (NDVI), obtained from the ratio between the reflectance difference in the near infrared band

and the red band, evaluates the spectral variability and changes in the vegetation growth. This index is related to the amount and condition of green vegetation (Matos et al., 2015).

The regular observation of a phenomenon provides the reconstruction of the historical context of the land cover evolution on the landscape scale from the time continuity (Zhai et al., 2014). Thus, the orbital images provide information about the terrestrial surface in local, regional and global scale, evidencing possible changes in the variable of interest. The use of time series to estimate the albedo from MODIS or Landsat images can capture the dynamics of the Earth's surface with high similarity with field data collected from the tower installation (Wang et al., 2017). Monitoring of vegetation with remote sensor systems over long periods is fundamental to gain a better understanding of processes related to vegetation change (Yin et al., 2012).

Associated with the information available in time series, trend analysis allows the knowledge of the behavior of a given phenomenon over time. This analysis is often used to identify significant variations in the series of environmental variables such as precipitation (Menezes & Fernandes, 2016; Durães et al., 2016), temperature (Salviano et al., 2016; Wanderley et al., 2016), evapotranspiration (Alencar et al., 2011), vegetation coverage (Neeti & Eastman, 2011; Lukes et al., 2016; Planque et al., 2017), among others.

For Alencar et al. (2014), the trend analysis refers to both continuous and systematic change observed in a time series, which describes the degree of increase or decrease of data over a period. Likewise, Some'e et al. (2012) points out that the presence of trends in time series can demonstrate the behavior of observed data in the light of an environmental phenomenon. For the characterization of tendencies of environmental phenomena, a non-parametric approach is often used, because of their ability to determine how much the slope coefficient of the adjusted line differs significantly from zero (Wagner et al., 2013).

In this sense, the Atlantic Forest of Brazil is one of the richest ecosystems in the world, being composed of forest formations and associated ecosystems (MMA, 2017), contributing significantly to the capture of pollutants from the atmosphere. However, it corresponds to one of the Brazilian biomes with the highest degradation rates, remaining only 12.5% of its original area, when fragments of more than 3 hectares were recorded (SOS Mata Atlântica, 2015) being primordial its monitoring through the years. Aiming at preserving these ecosystems, priority areas for biodiversity conservation were created, in which part of the National Forest (FLONA) of São Francisco de Paula (São Francisco de Paula, state of Rio Grande do Sul, Brazil) is covered by the Atlantic Forest Biosphere Reserve as a Core Area, being considered a region of "high" to "high priority" for conservation (MMA, 2002). FLONA is a conservation unit for sustainable use, which is characterized as an area of native forest cover associated with forest plantations and native field.

Forest plantations have been proposed as a strategy to mitigate climate change, and climate benefits are generally evaluated in terms of carbon sequestration potential, ignoring biophysical processes (Nabuurs et al., 2007). However, the impacts of biophysical variables such as albedo are crucial for analyzing the responses of land cover land use, land use change and forestry (LUCF) on climate (Planque et al., 2017), especially for tropical forests such as Atlantic forest.

Therefore, the goal of this study was to investigate the possible occurrence and causes associated with surface albedo trends within the Atlantic Forest biome during the last thirty years (1987-2017), evaluating the impacts of the forest cover structure on albedo trends.

2. Method

2.1 Spectral Data

The study area corresponds to the FLONA of São Francisco de Paula, which is located between the coordinates 29º27′29.91″ at 29º23′20.96″ south latitude and 50º24′53, 47″ at 50º22′39.01″ of West longitude. The FLONA belongs to the State of Rio Grande do Sul, in the South of Brazil. The area was monitored over 30 years and the summer period from 1987 to 2017 was observed annually. The spectral data used corresponded to TM/Landsat 5 and OLI/Landsat 8 images, which have a spatial resolution of 30 m.

Based on the TM/Landsat 5 and OLI/Landsat 8 images, the surface albedo was estimated by Equation 1. The albedo was calculated following the Surface Energy Balance Algorithm for Land (SEBAL) model, proposed by Bastiaanssen (1998), in which the atmospheric albedo (α_{atm}) can be obtained by means of a radiative transfer model, ranging from 0.025 to 0.04 (Allen et al., 2002). The SEBAL model allows to quantify the energy balance using satellite data as an input, being the value of 0.03 recommended for the SEBAL model (Liberato, 2011; Silva et al., 2016). Transmissivity for clear sky conditions, is described by Allen et al. (2002) as shown in Equation 2.

$$\alpha = \frac{\alpha_{toa} - \alpha_{atm}}{\tau_{oc}^{2}} \quad (1)$$

Where, α is the surface albedo; α_{toa} is the albedo at the top of the atmosphere (planetary); α_{atm} corresponds to the atmospheric albedo; τ^2_{oc} is the atmospheric transmittance.

$$\tau_{oc} = 0.35 + 0.627\ exp\left[-\frac{0{,}00146P_o}{K_t \cos Z} - 0.075\ \left(\frac{W}{\cos Z}\right)^{0.4}\right] \quad (2)$$

Where, P_o is the local atmospheric pressure (kPa); K_t is the turbidity coefficient of air (1.0 is for clean air and 0.5 is for extremely cloudy or polluted air); Z is the zenith angle; W is water precipitation (mm): $W = 0.14e_aP_o + 2.1$; e_a corresponds to the atmospheric water vapor partial pressure (kPa).

The αtoa was obtained by assigning weights to each of the bands, with images of the TM/Landsat 5 sensor using the following weights: 0.293ρ1 + 0.274ρ2 + 0.233ρ3 + 0.157ρ4 + 0.033ρ5 + 0.011ρ7, corresponding to bands 1, 2, 3, 4, 5 and 7. However, for OLI/Landsat 8 images the weights were 0.300ρ2 + 0.276ρ3 + 0.233ρ4 + 0.143ρ5 + 0.035ρ6 + 0.0119ρ7 for the bands 2, 3, 4, 5, 6 and 7, respectively.

2.2 Albedo's Relation to the Vegetation Greenery

In order to relate the vegetation's greenery to the variation of the surface albedo values, the vegetation index NDVI was used. Vegetation indexes explore the spectral properties of vegetation, especially in the red and near infrared regions. The dense vegetation reflects little in the red region due to the absorption of solar radiation by the foliar pigments, while the reflectance in the infrared region is higher due to the scattering of the radiation by the internal structure of the plant cells. Thus, developed by Rouse et al. (1973), the NDVI (Normalized Difference Vegetation Index) encompasses both regions, presenting a range of -1 to +1. This vegetation index is widely known and used for the monitoring of vegetation, since it is related to the vegetative vigor of the same. Green surfaces have a NDVI between 0 and 1 and water and cloud are usually less than zero.

2.3 Trend Analysis

In order to identify the albedo trends on the time series the Mann-Kendall statistical test was employed (Kendall, 1975; Mann, 1945), statistical tool suggested by the World Meteorological Organization (WMO) for the analysis of environmental variables over the time, such as albedo. The Mann-Kendall trend test was applied in the time series on the Landsat images, observing a period of 30 years and considering a 5% significance-level.

The Mann-Kendall test statistic considers the null hypothesis (H_0) when the data come from a population in which the random variables are independent and identically distributed. On the other hand, the alternative hypothesis (H_1) represents the existence of a monotonic tendency (Vilanova, 2014).

Subsequently, it was carried out the punctual analysis in areas that presented tendency when evaluated the surface albedo. The sample included 40 units (pixels) with increasing and decreasing trends. In the same way, the NDVI values were observed in these points in order to relate the two variables. For these samples was used the analysis of the standardized statistic of Mann-Kendall.

2.3.1 Tilt Test of Sen

The Mann-Kendall test does not provide the magnitude of the detected trends. Thus, the slope estimator proposed by Sen (1968) was used in combination with the trend analysis indicating the data slope degree of either increasing or decreasing albedo trends. The trend analysis was developed in programming language R version 3.4.3 (R Development Core Team, 2017). However, Qgis software version 2.16.3 was used to cut the area of study and conversion of the projections of the images.

3. Results and Discussion

After the albedo analysis over 30 years the trend test was applied, looking for patterns in the albedo behavior that occurred during the observed period. For each pixel, the Mann-Kendall test was performed considering the summer series from 1987 to 2017. The Figure 1 illustrated the points at which the null hypothesis of no trend in the series was rejected at the significance level of 5% for the albedo of surface.

Significant albedo changes are indicated in blue and red, corresponding to decreasing and increasing trends, respectively. The adjustment of a simple linear model to the annual surface albedo values showed a predominance of non-significant variations ($p > 0.05$) for the FLONA of São Francisco de Paula.

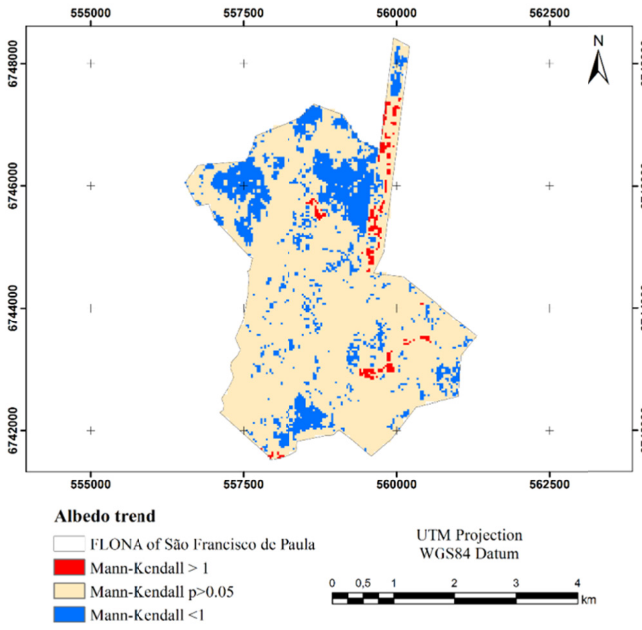

Figure 1. Evolution of the albedo tendency for the summer period of 1987-2017

The study area involved 17,496 pixels, of which 13,899 pixels presented a non-significant trend ($p > 0.05$), while 3,597 pixels showed a significant trend, corresponding to 20.6% of the image pixels. Among the significant pixels, 3,303 pixels were identified with negative albedo tendency, equivalent to 18.9% of the study area, while 294 pixels showed a positive trend, corresponding to 1.7% (Table 1). Thus, 91.8% of the significant pixels showed a decreasing tendency of the surface albedo.

In a study developed by Planque et al. (2017), analyzing the trend of albedo in France with data obtained from the Modis sensor, it was observed that approximately 3.5% of the study area showed a significant trend, of which 94% of the pixels were identified with a decreasing trend. Likewise, Salviano et al. (2016) when analyzing the precipitation trend in Brazil, identified that more than 70% of the Brazilian territory did not present significant trends.

Table 1. Albedo trend analyses values for the summer period 1987-2017

Trend analysis	**Numbers of pixels**	**Occupied area**	
		ha	**%**
Declining tendency	3,303	300.06	18.90
Non significant tendency	13,899	1,287.00	79.40
Increasing tendency	294	27.72	1.70

For samples with a temporal decrease, the surface albedo ranged from 0.2139 (1991) to 0.0930 (2007), presenting an average value of 0.1457 (Figure 2a). The Sen slope estimator test identified a slope value of 0.0038 for the declining trend sample, in other words, a drop on surface albedo values over the study period of 0.114 (Sen slope multiplied by the period). Therefore, an albedo decreased approximately 60% between 1987 and 2017.

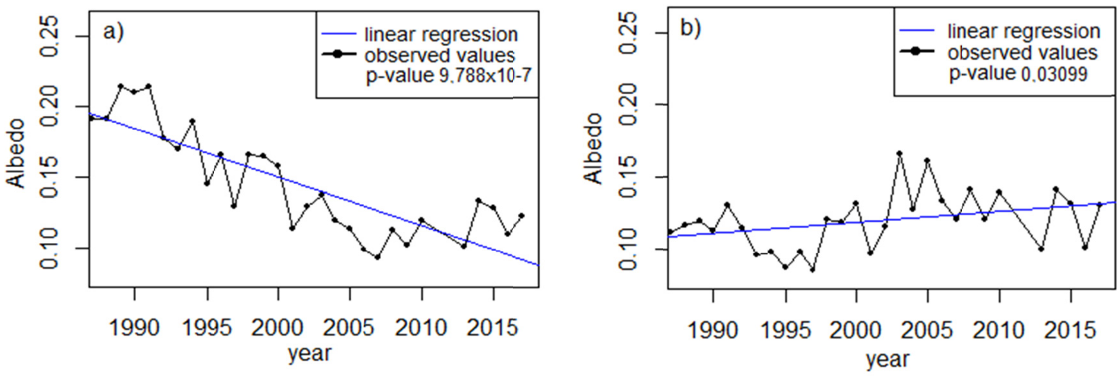

Figure 2. Surface albedo trends between 1987 and 2017 in sites with declining (a) and increasing (b) trends

The positive slope areas of the albedo showed a significant relationship of 0.03099, presenting a minimum value of 0.0850 in 1997, whereas in 2017 the maximum value was 0.1305 (Figure 2b). The inclination for the samples with increasing tendency according to the test of slope of Sen was of 0.00073, representing an increase of 0.0219 in the values of albedo in the observed period.

Thus, samples with a positive trend showed a 19.6% increase in albedo over the last 30 years. In general, the variation of the samples in the growing direction was less marked than that demonstrated by the decreasing samples. The areas with a positive trend showed a less significant relation when compared to the descending tendencies. These results are attributed to the changes in forest cover, making the canopy heterrogeneous and with this, variations in the albedo.

Further examination with the help of high spatial resolution images available in GoogleEarth ProTM (Google Inc., 2018) found that the points with decreasing trends corresponded to areas that were initially occupied by the native field at the beginning of the monitoring (1987). The native field presents in the form of forest masses interconnected with fields formations represented by Estepe Gramíneo-lenhosa. However, this cover was later replaced by homogeneous stands of *Pinus* spp. This change in coverage resulted in a change in the pattern of the spectral curve of the albedo, which presented a decreasing trend over the observed period.

Thus, there is a decrease in the summer period, close to 60% in the radiation reflected or emitted to the atmosphere in the study area when implanting forest plantations of *Pinus* spp. and *Eucalyptus* spp. These results corroborate the study developed by Planque et al. (2017) in woody forests, which identified the decrease of the albedo due to the greater degree of development of the arboreal vegetation. Similar behavior was observed by Davin and Noblet-Ducoudré (2010), who detected that the absence of forest cover results in increased surface albedo values.

At sampling points with increasing albedo tendency, changes in vegetation composition were also observed. Although the areas had vegetation coverage during the observed period, modifications occurred according to its structure. These sites at the beginning of the monitoring were occupied by homogeneous forest stands with a well-formed canopy structure. However, they were replaced by the natural vegetation cover of the Mixed Ombrofila Forest or Araucaria Forest, which has a slow development and subsoil spectral response of the vegetation, especially in the early years of its implantation. The history of changes in FLONA's coverage corroborates the low values of surface albedo identified, which are associated with forest cover (albedo of less than 14%).

With these results, it was observed that the vegetation cover level directly influences the albedo values; however the forest structure also seems to show a relation to the variation of this variable. Thus, the temporal evolution of NDVI was analyzed to understand the phenomena that occur in the areas of forest cover.

On the one hand, the Figure 3 shows the relationship between the surface albedo with decreasing trend and the NDVI (greenery of the vegetation). An inverse proportional relationship between the albedo and NDVI was observed, since the surface albedo decreased with increasing NDVI values, and this behavior was more pronounced in the last years of the monitoring. The NDVI showed a significant relationship ($p = 0.00731$), expressing an inclination of 0.0036, that is, an increase of 0.108 in NDVI values between the years 1987 to 2017.

The variables albedo and NDVI in the period from 1998 to 2003 presented values close to each other. However, since 2003, a change in the behavior assumed by these variables has been observed, evidencing the inverse relationship.

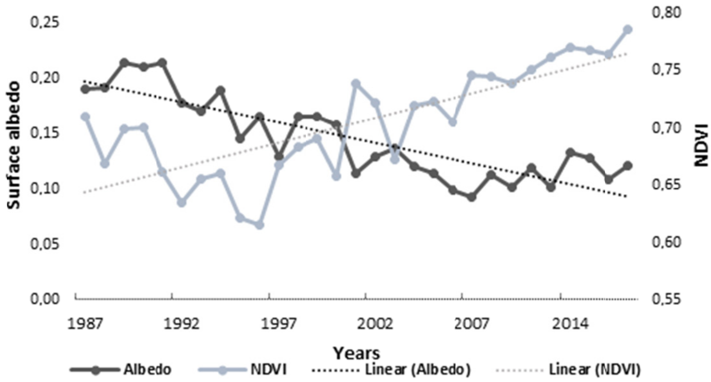

Figure 3. Relationship between surface albedo and vegetation greenery (NDVI)

As described above, the area initially housed a native field (Estepe Gramíneo-lenhosa), characterized by sparse vegetation, with influence of the soil exposed in the spectral response, but currently the images showed a significant increase of the vegetation and consequently an increase in NDVI values, while the values of albedo presented a gradual reduction. After 2004, the distance between the curves was more accentuated due to the absence of abrupt changes in the greenness indices of the vegetation at the points sampled.

High spatial resolution images available on GoogleEarth ProTM (Google Inc., 2018) confirmed the change in coverage in which the native field gave space to the forest plantings on the negatively slope sampled pixels. In this sense, when relating the surface albedo with the NDVI index, it was possible to identify, with some precision, information about abrupt changes in the area coverage, which explains the variations in the environmental component, the albedo.

This result goes towards the study developed by Planque et al. (2017) who observed an almost exact correlation between the increase in NDVI and albedo decrease from the albedo of the MODIS product to the forest cover of France. These authors verified that the studied pixels corresponded to forest areas predominantly occupied by broadleaved species.

The negative correlation between the albedo estimated by orbital sensors and vegetation properties was observed in other studies in forests of boreal conifers (Hovi et al., 2017). Lukes et al. (2016) analyzed the relationship between forest density and albedo from MODIS sensor data, identifying relatively strong negative linear correlations between forest density and albedo in the visible range.

For Otto et al. (2014), the albedo is sensitive to forest management. During the vegetative cycle, the albedo of the canopy is governed by the composition of arboreal species, extending until the establishment of the canopy; from this stage, the albedo is driven by the forest management.

Thus, the phenomenon that occurred in areas of Mixed Ombrophilous Forest of the Atlantic Forest may be related to canopy structure, since with the developed of the stands, the canopies become denser and with this the decrease of the albedo estimated by Landsat data. As result of the development of a forest, the canopy structure evolves to a higher hierarchical level with a higher number of shoots and branches, resulting in greater absorption of the incident energy and consequently albedo decrease (Planque et al., 2017).

On the other hand, for points with increasing albedo tendency, the NDVI showed an increasing slope, which is significant at the 5% confidence level, expressing a p-value of 0.0000043 with a slope of 0.0050 corresponding to 0.15 in the analysis period. Likewise, in this condition, it was identified the relationship of the vegetation with changes in albedo values (Figure 4). In this scenario, up to 2001, the behavior among the variables was similar, but in 2003 a fall in NDVI values was detected, and finally, from 2006 onwards, a gradual reduction of albedo values associated with an increase in NDVI values.

The pixel with an increasing trend of albedo encompassed areas for forest cover during the study period, but in the initial years of monitoring, similar values are observed between albedo and NDVI, which can be attributed to the fact that forest stands have a canopy structure formed and without structural changes, thus showing no significant trend of NDVI. In 2003 there is an abrupt change in the greenery of the vegetation associated to the increase of the albedo.

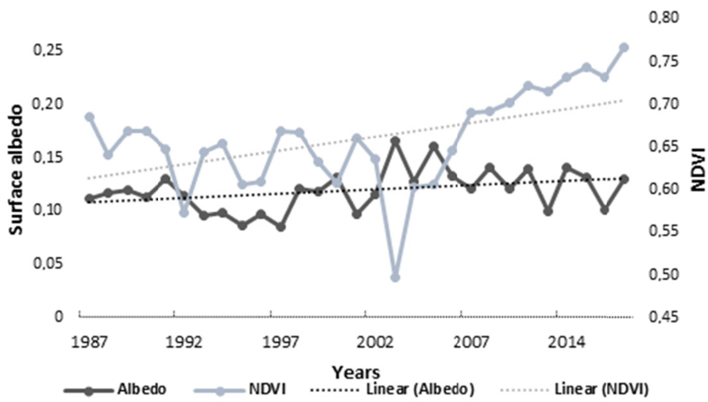

Figure 4. Relationship between vegetation greenery (NDVI) and surface albedo

Although high resolution images of this date are not available, it is possible to infer that in this period (2003) individuals could be cut and then the native forest gradually developed, which corroborates the behavior of albedo and NDVI after this date: increase of NDVI with forest development, while expressing a reduction of surface albedo values. Thus, when monitoring the area, a more pronounced decreasing behavior of the albedo could be identified due to the development of the native forest structure.

In this sense, the species composition influences the spectral response of the forest cover. The Mixed Ombrophilous Forest is the native cover of FLONA, being composed of coniferous and hardwood species. Lukes et al. (2016) conducted a separate analysis for conifer and deciduous species from a mask, and thus, they observed that the occupied areas, predominantly by deciduous species, had a higher albedo than the areas with conifers associated with lower NDVI values. Thus, NDVI is an important vegetation index widely used in multidisciplinary analyzes and its spatial and temporal large-scale information, representing an important indicator of the oscillation and succession of the terrestrial ecosystem (Hou et al., 2012).

In a study by Zanzarini et al. (2013), NDVI was presented as a means of analyzing the spatial variability of soil attributes used for agricultural crops. According to Gandhi et al. (2015), the NDVI index can be applied to examine the relationship between spectral variability and changes in vegetation growth rates due to their relationship to these properties.

In this sense, it confirms that the remaining arboreal vegetation of the Atlantic Forest biome corresponds to an important receptor and store of solar radiation due to its action of absorbing most of the incident energy. The forests cover importance for the maintenance of the energy flow between the surface and the atmosphere having great influence, especially under the factors influencing the local climate.

4. Conclusions

The Mann-Kendall test revealed the existence of negative slope for pixels where the native Field was replaced by Forest plantations of *Pinus spp*. and *Eucalyptus spp*. when observed a period of 30 years. Thus, the study shows that the forest stands present in areas of the Atlantic Forest biome have a large participation in the energy balance, which exposes a reduction of approximately 60% of the surface albedo in the summer with its implantation, showing its importance to reduce the emission of energy into the atmosphere.

A spatial pattern of the trend distribution of the surface albedo was identified along the study area, which is related related to the concentration and vigor of the arboreal vegetation. Further analysis of the greenery of the vegetation obtained on the basis of the NDVI index suggests that this climatic variable is governed by significant NDVI changes ($p < 0.05$), caused by the implantation of homogeneous forest stands. Thus, NDVI can be used as an indicator variable for the surface albedo for tropical forests such as the Atlantic Forest.

References

Alencar, L. P., Mantovani, E. C., Bufon, V. B., Sediyama, G. C., & Silva, T. G. F. (2014). Variação temporal dos elementos climáticos e da ETo em Catalão, Goiás, no período de 1961-2011. *Revista Brasileira de Engenharia Agrícola e Ambiental, 18*(8), 826-832. https://doi.org/10.1590/1807-1929/agriambi.v18n08p826-832

Alencar, L. P., Sediyma, G. C., Mantovani, E. C., & Martinez, M. A. (2011). Tendências recentes nos elementos do clima e suas implicações na evapotranspiração da cultura do milho em Viçosa-MG. *Engenharia Agrícola, Jaboticabal, 31*(4), 631-642. https://doi.org/10.1590/S0100-69162011000400002

Allen, R., Tasumi, I., Trezza, R., Waters, R., & Bastiaanssen, W. (2002). *Surface energy balance algorithms for land (SEBAL), Idaho implementation—Advanced training and users manual* (Version 1.0, p. 98).

Bastiaanssen, W. G. M., Menenti, M., Feddes, R. A., & Holtslag, A. A. M. (1998). Remote sensing surface energy balance algorithm for land (SEBAL)-Formulation. *Journal of Hydrology, 212-213*, 198-212. https://doi.org/10.1016/S0022-1694(98)00253-4

Davin, E. L., Noblet-Ducoudré, N. (2010). Climatic impact of global-scale deforestation: Radiative versus Nonradiative processes. *Journal of Climate, 23*, 97-112. https://doi.org/10.1175/2009JCLI3102.1

Durães, M. F., Mello, C. R., & Beskow, S. (2016). Trends in the hydrometeorological regime on an island in the South Atlantic Ocean. *Revista Brasileira de Climatologia, 18*, 242-255. https://doi.org/10.5380/abclima.v18i0.42673

Fundação SOS Mata Atlântica. (2015). *Relatório Anual*. Retrieved from https://www.sosma.org.br/projeto/atlas-da-mata-atlantica/dados-maisrecentes

Gandhi, G. M., Parthiban, S., Thummalu, N., & Christy, A. (2015). Ndvi: Vegetation Change Detection Using Remote Sensing and Gis—A Case Study of Vellore District. *Procedia Computer Science, 57*, 1199-1210. https://doi.org/10.1016/j.procs.2015.07.415

Global Climate Change. (2018). *Vital Signs of the Planet*. Retrieved July 16, 2018, from https://climate.nasa.gov

Google Inc. (2018). *Google Earth*. Retrieved January 05, 2018, from https://www.google.com/earth

Hovi, A., Lukes, P., & Rautiainen, M. (2017). Seasonality of albedo and FAPAR in a boreal forest. *Agricultural and Forest Meteorology, 247*, 331-342. https://doi.org/10.1016/j.agrformet.2017.08.021

Kendall, M. G. (1975). *Rank Correlation Methods*. London: Charles Griffin.

Liberato, A. M. (2011). Albedo à superfície a partir de imagens landsat 5—TM em áreas de floresta e pastagem na Amazônia. *Revista de Geografia, 28*(1).

Lukes, P., Stenberg, P., Mõttus, M., Manninen, T., & Rautiainen, M. (2016). Multidecadal analysis of forest growth and albedo in boreal Finland. *International Journal of Applied Earth Observation and Geoinformation, 52*, 296-305. https://doi.org/10.1016/j.jag.2016.07.001

Mann, H. B. (1945). Nonparametric Tests Against Trend. *Econometrica, 13*(3), 245. https://doi.org/10.2307/1907187

Matos, R. C. M., Candeias, A. L. B., & Azevedo, J. R. G. (2015). Análise multitemporal do albedo, NDVI e temperatura no entorno do reservatório de Itaparica-PE: anos de 1985 e 2010. *Revista Brasileira de Cartografia, 67*(3).

Menezes, F. P., & Fernandes, L. L. (2016). Análise de tendência e variabilidade da precipitação no estado do Pará. *Enciclopédia Biosfera, 13*(24), 1580-1591. https://doi.org/10.18677/EnciBio_2016B_146

MMA (Ministério do Meio Ambiente). (2002). *Avaliação e identificação de áreas e ações prioritárias para a conservação, utilização sustentável e repartição dos benefícios da biodiversidade nos biomas brasileiros* (p. 404). Brasília: MMA/SBF.

MMA (Ministério do Meio Ambiente). (2017). *Mata Atlântica*. Retrieved November 3, 2017, from http://www.mma.gov.br/biomas/mata-atlantica

Nabuurs, G. J., Masera, O., Andrasko, K., Benitez-Ponce, P., Boer, R., Dutschke, M., ... & Zhang, X. (2007). Forestry. In B. Metz, O. R. Davidson, P. R. Bosch, R. Dave, & L. A. Meyer (Eds.), *Climate Change 2007: Mitigation of climate change Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 541-584). Cambridge Univ. Pr, Cambridge, United Kingdom and New York, NY, USA.

Neeti, N., & Eastman, J. R. (2011). A Contextual Mann-Kendall Approach for the Assessment of Trend Significance in Image Time Series. *Transactions in GIS, 15*(5), 599-611. https://doi.org/10.1111/j.1467-9671.2011.01280.x

Ni, Y., Eskeland, G. S., Giske, J., & Hansen, J.-P. (2016). The global potential for carbon capture and storage from forestry. *Carbon Balance and Management, 11*(3), 1-8. https://doi.org/10.1186/s13021-016-0044-y

Nowak, D. J., Greenfield, E. J., Hoehn, R. E., & Lapoint, E. (2013). Carbon storage and sequestration by trees in urban and community areas of the United States. *Environmental Pollution, 178*, 229-236. https://doi.org/10.1016/j.envpol.2013.03.019

Otto, J., Berveiller, D., Bréon, F. M., Delpierre, N., Geppert, G., Granier, A., … Luyssaert, S. (2014). Forest summer albedo is sensitive to species and thinning: how should we account for this in Earth system models? *Biogeosciences, 11*, 2411-2427. https://doi.org/10.5194/bg-11-2411-2014

Planque, C., Carrer, D., & Roujean, J. L. (2017). Analysis of MODIS albedo changes over steady woody covers in France during the period of 2001-2013. *Remote Sensing of Environment, 191*, 13-29. https://doi.org/10.1016/j.rse.2016.12.019

R Development Core Team. (2017). *R: A language and environment for statistical computing*. Vienna: R Foundation for Statistical Computing. Retrieved from http://www.R-project.org

Rouse, J. W., Haas, R. H., Schell, J. A., & Deering, D. W. (1973). Monitoring vegetation systems in the great plains with ERTS. *Earth Resources Technology Satellite-1 Symposium, 3, 1974, Washington. Proceedings ...* (pp. 309-317). Washington: NASA.

Salviano, M. F., Groppo, J. D., & Pellegrino, G. Q. (2016). Análise de tendências em dados de precipitação e temperatura no Brasil. *Revista Brasileira de Meteorologia, 31*(1), 64-73. https://doi.org/10.1590/0102-778620150003

Sen, P. K. (1968). Estimates of the regression coefficient based on Kendall’s Tau. *Journal of the American Statistical Association, 63*, 1379-1389. https://doi.org/10.1080/01621459.1968.10480934

Silva, B. B., Braga, A. C., Braga, C. C., Oliveira, L. M. M., Montenegro, S. M. G. L., & Barbosa Júnior, B. (2016). Procedures for calculation of the albedo with OLI-Landsat 8 images: Application to the Brazilian semi-arid. *Revista Brasileira de Engenharia Agrícola e Ambiental, 20*(1), 3-8. https://doi.org/10.1590/1807-1929/agriambi.v20n1p3-8

Some’e, B. S., Ezani, A., & Tabari, H. (2012). Spatiotemporal trends and change point of precipitation in Iran. *Atmospheric Research, 133*, 1-12. https://doi.org/10.1016/j.atmosres.2012.04.016

Souza, W. M., & Azevedo, P. V. (2012). Índices de Detecção de Mudanças Climáticas Derivados da Precipitação Pluviométrica e das Temperaturas em Recife-PE (Detection Indexes Derived from Climate Change Rainfall and Temperatures in Recife-PE). *Revista Brasileira de Geografia Física, 5*(1), 1-17. https://doi.org/10.26848/rbgf.v5i1.232793

Tian, L., Zhang, Y., & Zhu, J. (2014). Decreased surface albedo driven by denser vegetation on the Tibetan Plateau. *Environmental Research Letters, 9*(10). https://doi.org/10.1088/1748-9326/9/10/104001

Vilanova, M. R. N. (2014). Tendências hidrológicas anuais e sazonais na bacia do rio Paraibuna, Parque Estadual da Serra do Mar (SP). *Sociedade e Natureza, 26*(2), 301-316. https://doi.org/10.1590/1982-451320140208

Wagner, A. P. L., Fontana, D. C., Fraisse, C., Weber, E. J., & Hasenack, H. (2013). Tendências temporais de índices de vegetação nos campos do Pampa do Brasil e do Uruguai. *Pesquisa Agropecuária Brasileira, 48*(9), 1192-1200. https://doi.org/10.1590/S0100-204X2013000900002

Wanderley, H. S., Justino, F. B., & Sediyama, G. C. (2016). Tendência da Temperatura e Precipitação na Península Antártica. *Revista Brasileira de Meteorologia, 31*(2), 114-121. https://doi.org/10.1590/0102-778631220140146

Wang, Z., Schaaf, C. B., Sun, Q., Kim, J., Erb, A. M., Gao, F., … Papuga, S. A. (2017). Monitoring land surface albedo and vegetation dynamics using high spatial and temporal resolution synthetic time series from Landsat and the MODIS BRDF/NBAR/albedo product. *International Journal of Applied Earth Observation and Geoinformation, 59*, 104-117. https://doi.org/10.1016/j.jag.2017.03.008

Zanzarini, F. V., Pissarra, T. C. T., Brandão, F. J. C., & Texeira, D. D. B. (2013). Correlação espacial do índice de vegetação (NDVI) de imagem Landsat/ETM+ com atributos do solo. *Revista Brasileira de Engenharia Agrícola e Ambiental, 17*(6), 608-614. https://doi.org/10.1590/S1415-43662013000600006

Zhai, J., Zhai, J., Liu, R., Zhao, G., & Huang, L. (2014). Radiative forcing over China due to albedo change caused by land cover change during 1990-2010. *Journal of Geographical Sciences, 24*(5), 789-801. https://doi.org/10.1007/s11442-014-1120-4