IMPACT OF DEFORESTATION ON THE PROPOSED MESOAMERICAN BIOLOGICAL CORRIDOR IN CENTRAL AMERICA

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Abstract

This study uses the dry season Normalized Difference Vegetation Index (NDVI) of 1982 to 2000 derived from Advanced Very High Resolution Radiometer (AVHRR) to identify regions of substantial deforestation in Central America. High-resolution nested grid simulations, using the Colorado State University (CSU) Regional Atmospheric Modeling System (RAMS), are conducted over the identified regions of deforestation. These simulations examine cloud formation for three land use scenarios: 1) completely forested; 2) current land use; and 3) deforested conditions. In the deforestation scenario the locations of the proposed Mesoamerican Biological Corridor (MBC) are kept forested while pasture conditions are assumed for other areas. These simulations help identify locations where high deforestation has significant climatic impact on the proposed biological corridor. Model simulations show that with pastures surrounding forests in the proposed corridor, several locations within the corridor will have suppressed cloud formation.

1. INTRODUCTION

Several studies show links between land use and regional climate. Land use impacts regional climate by modulating the surface energy budget. The surface energy budget in turn is dependent on the characteristics of the landscape, such as vegetation cover, soil type, surface roughness, soil moisture distribution, albedo and temperature Pielke, (2001). Land use and landscape heterogeneity impacts boundary layer air temperature and moisture, depth of the boundary layer, cloudiness, cloud properties and local rainfall (Nair et al., 2003; Ray et al., 2003).

Mesoamerica, a region that hosts significant biodiversity, is currently subject to drastic rates of deforestation. Serious concerns of ecosystem fragmentation and habitat isolation has generated interest in the establishment of a network of biological corridors called the Mesoamerican Biological Corridor (MBC). This study examines whether or not the land use changes in the surrounding regions impact the regional climate within these protected biological corridors. The AVHRR derived NDVI dataset is used to identify locations experiencing rapid rates of deforestation in Northern Central America, the region of interest for the present study. Numerical simulation of cloud formation is conducted using RAMS for three scenarios: 1) Completely forested (past); 2: Current conditions; and 3: Completely deforested except for the proposed corridors (future).

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2. DATA

Deforestation during the last two decades in the study region, i.e., northern part of Central American region approximately bounded within 13°N to 19°N and 94°W to 86°W is analyzed using NDVI derived from the AVHRR. The AVHRR derived NDVI data set, at 8 km spatial resolution, is available for the time period spanning from 1982 to 2001 (Zhou et al., 2002).

Meteorological observations from the upper air and surface observation networks along with the National Centers for Environmental Prediction (NCEP) reanalysis data set Kalnay et al., (1996) is used to initialize RAMS and specify temporally varying lateral boundary conditions. Land use categories derived from the Moderate Resolution Imaging Spectroradiometer (MODIS) are used to specify surface vegetation types in the RAMS (Hansen et al., 2000). Digital maps of the proposed MBC, MODIS derived land use database and the trends of deforestation identified from the AVHRR NDVI data analysis are used to construct future land use scenario.

3. METHODOLOGY

3.1 Analysis of trends of deforestation in the study area

The AVHRR derived NDVI dataset is used to analyze the deforestation trends in the study region. The observed temporal changes in NDVI at a location are due to several factors such as seasonality, water availability (rainfall) and land use change. The effect of deforestation on NDVI is embedded within the overall pattern of NDVI changes. When comparing decadal changes in NDVI over a specific location, the effect of seasonality and water availability is minimized by using the NDVI data for the same time of year and for years with similar rainfall patterns. This study used consistently the well established dry season month of March for NDVI comparisons. The NDVI data for March of 1982 and 2000 is used in this study. Note that regional rainfall patterns for the preceding years show similar rainfall patterns also during the wet season. The National Oceanic and Atmospheric Administration (NOAA) Cooperative Institute for Research in Environmental Sciences (CIRES) climate data Kalnay et al., (1996) is used to analyze the regional rainfall pattern in this region to differentiate the dry, normal and wet years from 1982 to 2001. This dataset is used to identify years with normal and consistent rainfall pattern for (1) the entire dry season; (2) on both the Pacific and the Atlantic side; and (3) the wet season rainfall proceeding the dry season. Using these three criterions, the years 1982, 1990, 1997 and 2000 were chosen as years with comparable rainfall pattern. The difference in NDVI between these years, for the month of March, is examined to identify regions of deforestation in the study region.

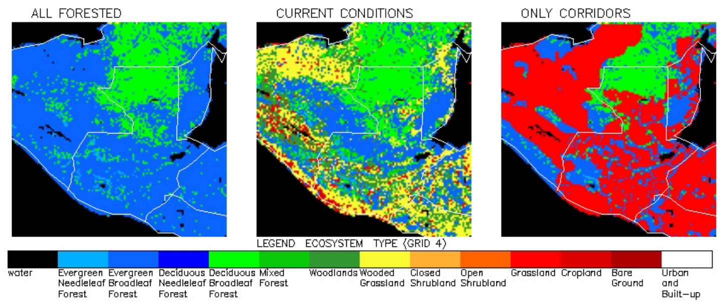

Figure 1. The land use prescribed for the three model simulations. In the all forested scenario the entire domain is converted to forests. Current condition has land use as observed currently; and the only corridors land use case assumes that the protected regions (marked in blue and green will become or remain forested whereas outside these regions the land use will get converted into pastures (marked in red)

The effect of deforestation in surrounding regions on the local climate within the MBC is examined using the RAMS numerical model simulations. A nested grid configuration is used in the experiments; an outer grid with coarse spacing is used to resolve large-scale features in the atmospheric flow and progressively finer spaced grids are used to resolve smaller scale features. The configuration of the nested grids used in this study is given in **Table 1** and the location for the innermost, fine space nested grid is shown in **Figure 1** for the three models run. All the simulations in this study utilized the same atmospheric initial conditions and temporally varying boundary forcing, derived from meteorological observations and NCEP reanalysis data valid for the time periods of March 1,

3.2 Numerical simulation experiments

TABLE 1

	MESH	SPACING	LATITUDE AND LONGITUDE
1	14X14	Δ = 320km	NW (34.0, -111.0) NE (34.0, - 67.0) SW (-2.0, -107.1) SE (-2.0, - 71.0)
2	30X30	Δ = 80km	NW (28.3, -102.3) NE (28.5, - 78.9) SW (7.8, -100.9) SE (7.9, - 80.0)
3	62X62	Δ = 20km	NW (21.2, - 96.8) NE (21.4, - 85.0) SW (10.3, - 96.4) SE (10.4, - 85.3)
4	62X62	Δ = 5km	NW (19.0, - 93.8) NE (19.0, - 87.8) SW (13.3, - 93.6) SE (13.4, - 87.9)

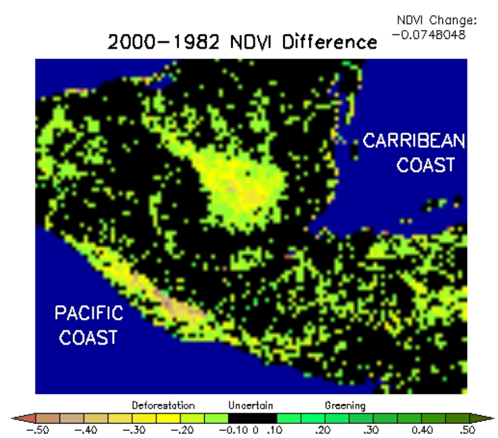

Figure 2. Change detection in Northern Central America using NDVI difference between 1982 and 2000 March. Both of these months had similar dry season rainfall for the current year and for the previous year's wet season. The assumption is that the region was covered with forests in 1982 and deforestation took place somewhere between 1982 and 2000, and therefore the NDVI changes observed are due to conversion of forests to low NDVI deforested landscapes.

through March 15, 2001. The three different model simulations considered in this study differed only in the nature of land use, with the different scenarios as shown in Figure 1. In the first case of past land use scenario, all the areas that are currently covered by forest (as determined from MODIS land use data) are assigned similar land use categories. Areas that are currently deforested are assumed to be evergreen broadleaf forests in the first land use scenario. The second scenario assumes current land use specified by the database derived from MODIS (Hansen et al., 2000). In the third scenario, the regions within the MBC are specified to have the current observed land use categories if forested or converted to evergreen broadleaf forests if they are currently deforested while other regions are converted to pastures. In the third land use scenario, the assumption that all the deforested areas are converted to pastures is drastic. However, it represents the worst-case scenario.

Starting from the initial conditions consistent with that of 12 UTC of March 1, 2001, the different simulations were integrated for a period of 15 days. The 15-day average of the diurnal variations of air temperature, sensible heat flux, latent heat flux, planetary boundary layer height, and cloud cover for the three simulations are compared. The comparisons are done for the protected regions, as well as, for the surrounding regions.

Correlations between satellite derived cloud cover and ground based rainfall observations indicate a strong correlation between afternoon cloudiness and rainfall, especially in the dry season. Thus any changes in cloud formation during the dry season can potentially impact the ecologically sensitive MBC. The simulations are used to examine changes in cloud formation if the protected regions are forested but the regions outside are (1) forested or (2) completely deforested. A third case of current conditions, in which the protected regions are left as seen currently and the areas lying outside the proposed protected areas are also left as such was also analyzed and compared with the other two cases.

4. RESULTS

4.1 Deforestation trends:

Figure 2 shows the NDVI differences between the years 1982 and 2000. The effect of deforestation is clearly visible in the figure showing the NDVI change between 1982 and 2000. Incidentally this is a region, which has been earmarked as 'Other Use' category in the proposed MBC. Several of the proposed corridors connecting 'Parks and Reserves' to the north, south, west and east will pass through this region. Another region that clearly show deforestation between 1982 and 2000 is in the Pacific region. The corridor is expected to contain regions to the east of this area. The NDVI analysis shows that the large-scale deforestation assumed in the future land use scenario is not unrealistic. However, as discussed in the previous section, the assumption that all the deforested areas are converted to pastures is unrealistic, but represents the worst-case scenario. Further simulations

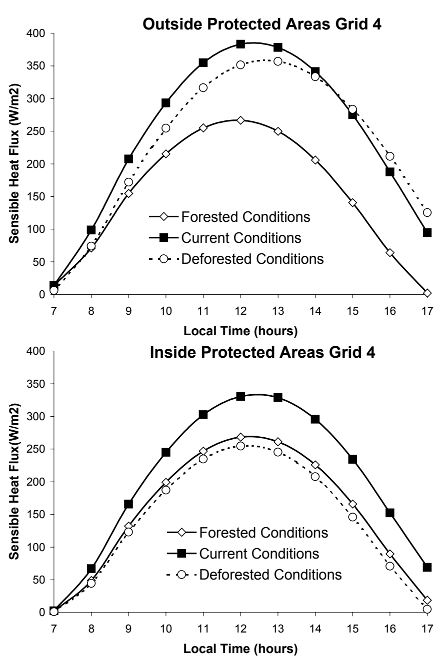

Figure 3 Diurnal Variation of Sensible Heat flux averaged over 15 days for the three models.

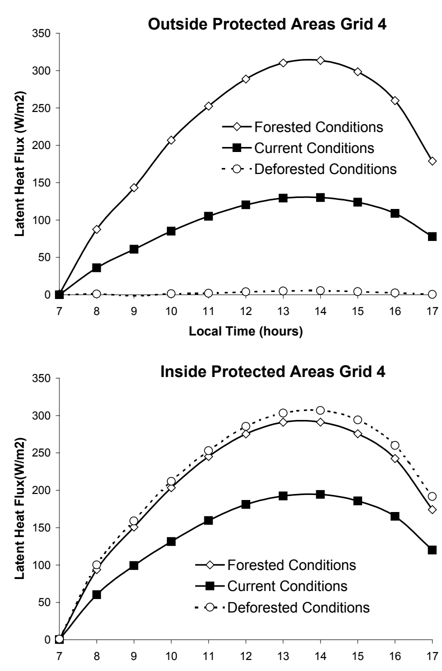

Figure 4 Diurnal Variation of Latent Heat Flux averaged over 15 days for the three models.

with more realistic scenarios are currently under way.

4.2 Numerical Modeling Results:

4.2.1 *Diurnal variation of sensible and latent heat flux*

Land use change leads to significant differences in the sensible and latent heat fluxes (**Figures 3 and 4**). In addition to differences in the amount of solar energy absorbed at the surface by forests and pastures, trees in the forest access water stored in deeper soil layers compared to grasses. Therefore in areas not protected through the MBC initiative the deforestation would generally lead to a sharp increase in sensible heat fluxes and lower latent heat fluxes. The deforestation outside the protected regions influences the energy partitioning inside the protected regions as well, but the effect when averaged over the entire domain is not very different from that of a forested scenario. The low values of latent heat flux over the pastures in the future scenario is due to shallow roots in the pastures accessing drier upper soil layers. A more realistic model of the future scenario is now being run to address these issues.

4.2.2 *Diurnal variation of planetary boundary layer height and clouds*

The RAMS simulations indicate that the enhanced surface sensible heat flux due to deforestation leads to higher planetary boundary layer (**Figure 5**). Within the protected regions (that are forested) the planetary boundary layer is nearly identical except in the late afternoon hours. However the effect of these differences on cloud formation is non-linear. The differences outside the protected areas reduced the cloud formation as shown by the decrease in the diurnal cloud fraction especially at early morning and late afternoon times (**Figure 6**). The deforestation outside the protected areas also leads to decrease in cloud formation within the protected areas. These domain averaged results raise the question whether or not all the protected regions will be equally impacted due to deforestation.

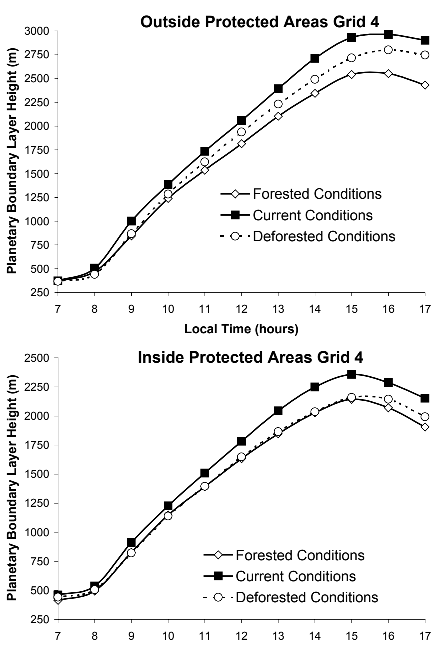

Figure 5. Diurnal variation of planetary boundary layer height averaged over 15 days for the three model runs.

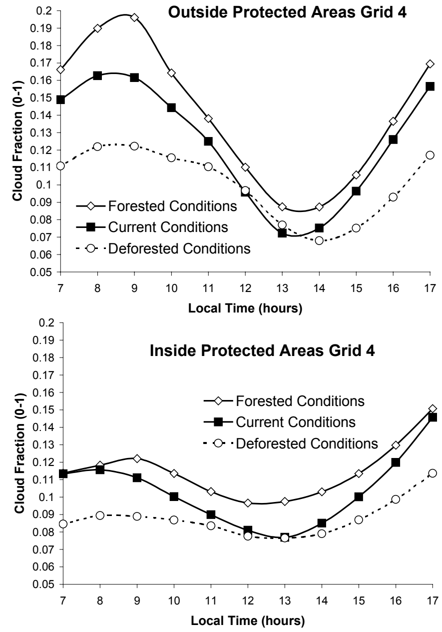

Figure 6. Diurnal Variation of Cloud fraction averaged over 15 days for the three models.

5. CONCLUSIONS

The results suggest that deforestation outside the protected regions does not greatly alter the sensible and latent heat fluxes and the planetary boundary layer heights within protected regions dramatically from a condition where outside the protected regions forests are present. However, the deforestation has significant impacts on cloud formation. Results suggest if further deforestation outside the protected regions continues then the cloud formation would decrease especially at early morning and late afternoon times.

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