Accuracy assessment, land cover patterns and capacity-building in the trinational Acre River Basin: pieces of the jigsaw puzzle of sustainable development in Southwestern Amazonia.

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1. Introduction

The Upper Acre River Basin covers 7,590 km^2 of Bolivian, Brazilian and Peruvian territories and represents one of several international river basins in Amazonia. The integrated management of this basin depends on information on land cover patterns that can be exchanged among three countries. The Program of Deforestation Estimates of Amazonia (PRODES) of the National Institute of Space Research (INPE) has measured land cover in the Brazilian side of the basin since 1978 and produces data for monitoring and control of deforestation in the Brazilian Amazon. These data are now readily available via the Internet. INPE has also developed a RS/GIS software package, called SPRING, available as freeware in both Portuguese and Spanish.

Given the availability of PRODES data and of free SPRING software in local languages, our first objective was to evaluate the precision and accuracy of the original PRODES method, using Landsat TM imagery of 2002 and to propose a modification of PRODES method for use in the region. Our second objective was to use this modified method in combination with digital elevation data for prioritizing sub-basins for more detailed studies and mapping riparian forest zones. Our third objective involved capacity building in the three countries so to facilitate the use of this method for river basin management in this frontier region .

2. Precision and accuracy of the PRODES method

We tested the PRODES method and its modification using Landsat TM image 002/67, (10Aug02) and subsets (Figure 1). The reproducibility of the deforested area, compared with an analysis done by INPE, was within 5% for the entire image and <3.5% for subsets for the standard method. The sequence of the method is shown in Figure 2.

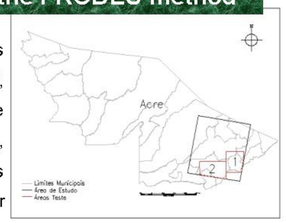

Figure 1. Localization of the study area in Acre State, showing the limits of image 002/67 (black) and the two test areas (red)

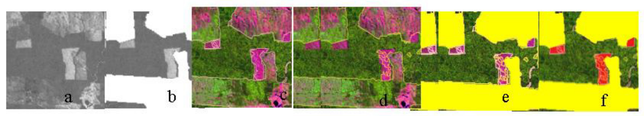

Figure 2. Sequence of the standard PRODES method: (a) soil-fraction image obtained by application of spectral mixing model; (b) soil-fraction image with application of mask of previous deforestation; (c) segmentation of soil-fraction image; (d) segmentation of shade-fraction image; (e) superpositioning of soil-fraction image (pink lines) and shade-fraction image (yellow lines) on Landsat image for editing (yellow – previous deforestation); and (f) classification (yellow – previous deforestation; red – new deforestation.

To map areas such as those of subsistence agriculture that are frequently less than the minimum area mapped by the standard PRODES method, although visible in the image (Figure 3a), the following modifications were made (Figure 3b):

>> no application of a mask of previous deforestation;

>> use of spatial resolution of 30 m in place of 60 m and minimum area of 0.36 ha.

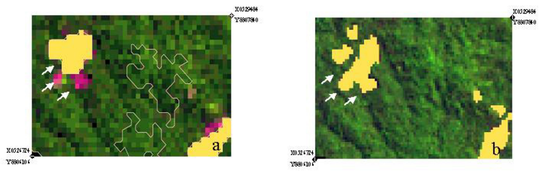

Figure 3. (a) Detail of classification with standard PRODES method (spatial resolution: 60 m), showing areas that are excluded from the classification. The yellow polygons are the mask of previous deforestation estimates. (b) Detail of classification using the modified method (spatial resolution: 30 m), showing the inclusion of these areas and the exclusion of others with forest cover. The yellow polygons refer to the extension of deforestation in 2002.

The extension of deforested area derived from the modified method in the test area was 929 km^2. The standard PRODES method estimated 1080 km^2 of deforested area, a difference of 14%. We used a QuickBird image (21jun02) of 125 km^2 for accuracy assessment of the modified PRODES method for deforested and forested areas. The QuickBird image was three-quarters deforested. Over-all accuracy was 94% on an areal basis. The modified PRODES method applied to Landsat imagery sub-estimated total deforested area by 4% (Landsat = 91.5 km² and QuickBird = 95.6 km²), and super-estimated total forest area by 17% (Landsat = 31.9 km² and QuickBird = 27,3 km²). We adopted ±10%, as an approximation for overall uncertainty. Inclusion and exclusion errors for deforested area were 1% and 6%, respectively.

3. Analysis of forest cover in the basin

The Digital Elevation Model (DEM) of the Shuttle Radar Topographic Mission (SRTM) was analysed using IDRISI 32 software to determine the basin watershed, drainage network, and relief (Figure 5). The drainage network used a minimum of 80 ha of drainage to initiate the network. Field observations showed that drainage and riparian forests are frequently associated with 20 to 60 ha of drainage, so the generated network is conservative in length and extent.

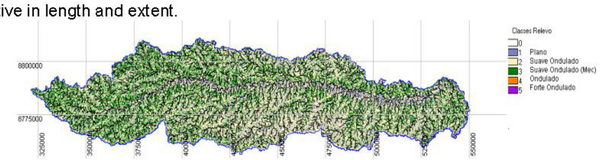

Figure 5. Map of relief classes of the Acre River Basin, using the classification scheme of the Brazilian Society of Soil Science (EMBRAPA, 1999), the drainage network (black lines) and basin limites (blue line).

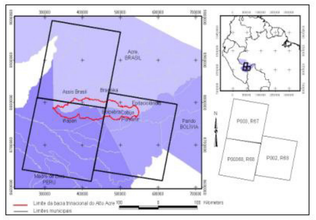

Figure 6. Images used for analysis of deforestation in the trinational Acre River Basin.

To determine the deforested area in the basin we used the modified PRODES method on subsets of Landsat TM images 002/67 (26Aug02) and 003/67 and 003/68 (16Jul02) that cover the Upper Acre River Basin (Figure 6).

The extent of deforestation of riparian forests (mata ciliar) was measured by applying a buffer 30 m from the derived drainage network using ArcView 3.2. The result of this operation was compared with forest cover, using SPRING 4.1 (Figure 7).

Figure 7. (a) Details of the drainage network (light blue) derived from the DEM and the buffer zone of 30 m each side (red lines), superposed on the Landsat TM image. (b) Intersection of buffer zone with classes of deforested areas (yellow) and forested areas (verde). (c) Resulting intersection of buffer and land cover classes. Note the effect of using 80 ha as a minimum area, smaller riparian areas (deforested or forested) were not included (see examples of black circles). Field observations indicate that these areas suffer proportionally even more deforestation than along the larger streams.

The total area deforested in the trinational basin, using the modified PRODES method was 13 % (1014 km^2 ± 10%) in 2002 (Figure 8). The distribution of deforested area by country can be seen in Figure 9, which shows that most deforestation is concentrated in Brazil.

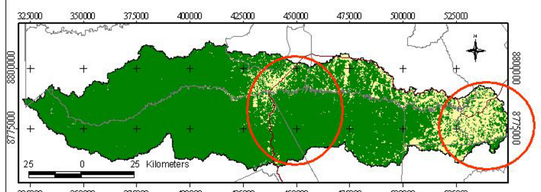

Figure 8. Map of the extent of deforestation (in yellow) in 2002, covering 13% of the trinational Upper Acre River Basin. The other classes correspond to forest (green) and clouds (grey). The grey lines are municipal boundaries and the brown line corresponds to the Interoceanic Highway. Note the two foci of deforestation can be seen within the red circles.

Figure 9. Distribution of deforested area in the Upper Acre River Basin by country in 2002. .

We thank Researchers Valdete Duarte, Yosio Shimabukuru and Dalton Valeriano of the National Institute for Space Research – INPE for providing information and training in the use of the PRODES method.

The areas of large-scale deforestation were partitioned into sub-basins to analyse the distribution of deforestation and relief for erosion risk analysis and to quantify of the degree of deforestation of riparian forests (Figure 10). The sum of the areas of these sub-basins corresponds to 25% of the total area of the basin. These sub-basins contain 58% of the total deforested area of the Upper Acre River Basin.

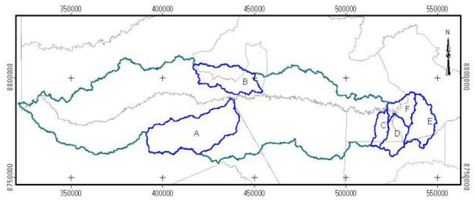

Figure 10. Priority sub-basins for conservation and recuperation: (A) Yaverija; (B) Grande; (C) Virtude; (D) Bahia; (E) Igarapé Barra e (F) Section of Acre River in the vicinity of the cities of Brasiléia, Epitaciolândia, and Cobija.

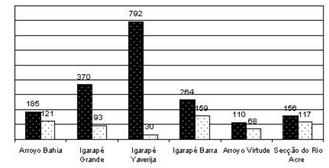

Figure 11. Total area (black) and deforested area (white) in km² of the six piority sub-basins of the Upper Acre River Basin in 2002.

In terms of riparian forests, the Yaverija sub-basin is well-preserved, with only 5% of its riparian forests (±30 m buffer) without their original forest cover. It is also the largest sub-basin and the one with the least absolute amount of deforestation. The riparian forests of the Barra sub-basin were the most impacted by deforestation (137 km) with 83% having been deforested (Figures 11 and 12).

The relation between kilometers of riparian forests in the six sub-basins (477 km) and the areal extent of deforestation (589 km^2) is 0.8 km/ km^2. This relationship is conservative due to the large minimum drainage of 80 ha. Deforested riparian forests in smaller drainages were not measured.

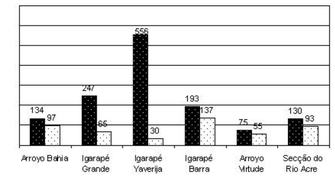

Figure 12. Total extension (black) and deforested extension (white) in km of riparian forests in each of the six piority sub-basins of the Upper Acre River Basin in 2002.

Figure 13. Example of lectures and training to prepare local groups in the use of SPRING software for RS/GIS analysis to support river basin management. Classroom in National Univresity San Antonio Abad del Cusco (UNSAAC), Puerto Maldonado, Madre de Dios, Peru. First author giving lecture, 31Jan05.

We have begun capacity-building in Cobija, Pando, Bolivia, Puerto Maldonado, Madre de Dios, Peru, and Brasileia, Acre, Brazil to prepare local groups in the use of SPRING software to analyse the data sets and imagery such that of CBERS for river basin management. Over a hundred persons participated in the first phase of this training (Figure 13).

4. Conclusions

• The error of reproducibility of the standard PRODES method was ≤ 5% in estimating deforested area, suggesting that the method is sufficiently robust to be disseminated among local institutions in the Madre de Dios, Peru – Acre, Brazil – Pando, Bolivia (MAP) Region for land cover measurements.

•To map riparian forests, the standard PRODES method was modified to provide higher resolution. The modifed and standard PRODES methods differed by 13% in deforested area of test areas, principally due to the use of a mask of prior deforestation that hides forest fragments in the standard method. A comparison with data derived from Quickbird imagery indicates that the relative uncertainty in accuracy for the modified PRODES method is on the order of 10%.

•The modified PRODES method estimated that 13% (± 1,3%) of the area of the Upper Acre River Basin was deforested by 2002. Most of this deforestation is concentrated in six sub-basins separated into two groups.

•The average ratio of extension of deforested riparian zone to area deforested is 0.8 km/km^2 in the six sub-basins. If this relationship is representative of deforested areas in Acre, then >10,000 km of deforested riparian zones exist in Acre State.

•Several groups the three countries wish to use the software and images applied in this study in regional planning exercises in the MAP Region. The perspective of free software and imagery has motivated several individuals to seek further training so to be able to contribute to regional planning of land use and river basin management.