# Land Use Changes and Deforestation in the Alto Mayo Valley, North Peru

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## Motivation

Clearing of pristine forests by small scale farming is the main cause of deforestation in the Alto Mayo Valley in Northern Peru. The large flat valley at the eastern slope of the Andes attracts many peasants from the overpopulated Andean highlands (Fig. 1).
The continuing influx of small-hold farmers results in a rapid and largely uncontrolled conversion of pristine neotropical forest fringes into pasture and agricultural areas. In our study we did the first analysis on the rate of land conversion for the entire Alto Mayo region based on satellite imagery.

## Land Use Change

Eight classes (primary forest, secondary vegetation, abandoned areas/pasture, open/burnt soil, alpine grassland, rice, river/rice, urban areas) were obtained (Fig. 3).
A cloudless 57 000 ha subset (7.1%) was chosen for land use change detection (Tab. 1). It reveals a high pressure on primary forest as well as considerable conversion rates for secondary vegetation and fallow areas.
Most of the primary forest along the sloped forest fringes is now converted into coffee plantations (red). The valley plains are suitable for rice cultivation and had already been cleared in the early 1980's (Fig. 4). Therefore, only previously untouched areas belonging to native tribes are now still available for new rice fields (blue) as seen in Fig. 5.

## Deforestation

In the Alto Mayo valley, cloud cover concentrates over the remote mountain ranges that still retain much of their original forest cover. Since these areas cannot be image classified, we developed several scenarios based on different reference systems (Tab. 2).
The margin between such a minimum scenario (all clouded areas assumed to still bear primary forest which is likely, considering that clouds mostly cover the higher mountain ranges bordering the valley) and a maximum scenario (only unclouded areas assessed with a strong bias to the accessible valley bottom) is demonstrated in Fig. 6. The most realistic estimation is based on the subset mentioned above (Fig. 6; red circles).
A significant acceleration trend of deforestation since the mid 1990's remains. We assume that the annual deforestation rate increased from less than 1% in the late 1980's to currently almost 5%.

## Conclusions

Forest conversion even in Comunidades Nativas (CN) has also increased in recent years and their deforestation rates are likely to soon reach an alarming level due to improved access to transport, markets and technology.
Our findings exceed the deforestation predictions for the late 1990's proposed by a study from a Peruvian NGO (APECO, 1995). The APECO study used demographic and administrative data. Their prediction of the demographic development trend was correct whereas their data source for land use resulted in a strong underestimation of deforestation.
This discrepancy demonstrates the need for an independent evaluation of land use changes from space for governmental planning and decision making.

## Literature


- APECO (1995): Bases para la Gestión de los Recursos Naturales y Elaboración de un Plan de Ordenamiento Territorial de la Región San Martín.- Asociación Peruana para la Conservación de la Naturaleza, Lima
- YOUNG, K.R. (1992): Biogeography of the montane forest zone of the eastern slopes of Peru.- In: YOUNG, K.R.; VALENCIA, N. (Eds.): Biogeografía, ecología y conservación del bosque montano en el Perú. – (Lima) **21**: 119-154





**Fig. 1:** Edited NOAA-AVHRR image of Peru showing the location of the study site. The graphic emphasizes the natural zonation of the country in the narrow arid coastal strip (**yellow**), the over-populated highlands (**brown**), the lower Andean Cordilleras (**dark green**) and the Amazon lowlands (**light green**) according to Young (1992).

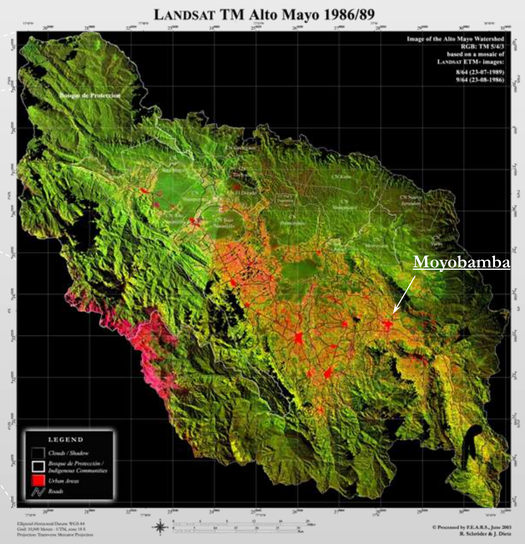



**Fig. 2:** Original LANDSAT TM mosaic (RGB: TM 5/4/3) from 1986 (west) and 1989 (east) after cloud masking. Significant differences in topographic illumination are conspicuous. Elevations range between 600 and 4 500 m a.s.l..

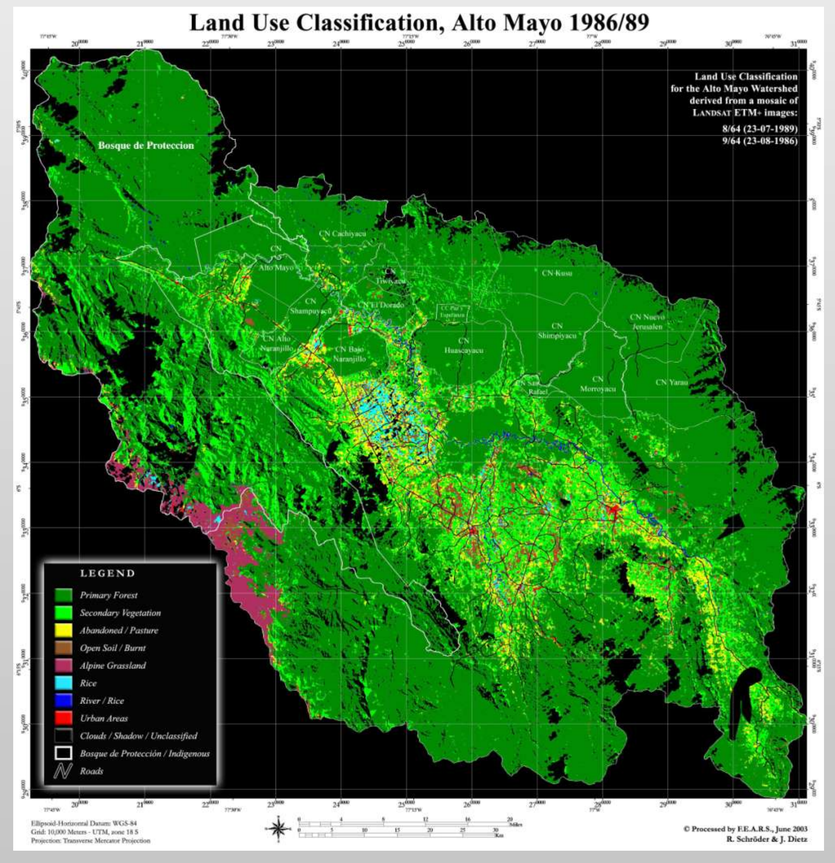



**Fig. 3** ▸ Result of a hybrid classification of the LANDSAT TM mosaic from 1986/89 (Fig.2) picturing the initial reference state for the following land use change observations. Outlined are actual and projected roads as well as the boundaries of indigenous community estates and a local forest sanctuary ("Bosque de Protección").

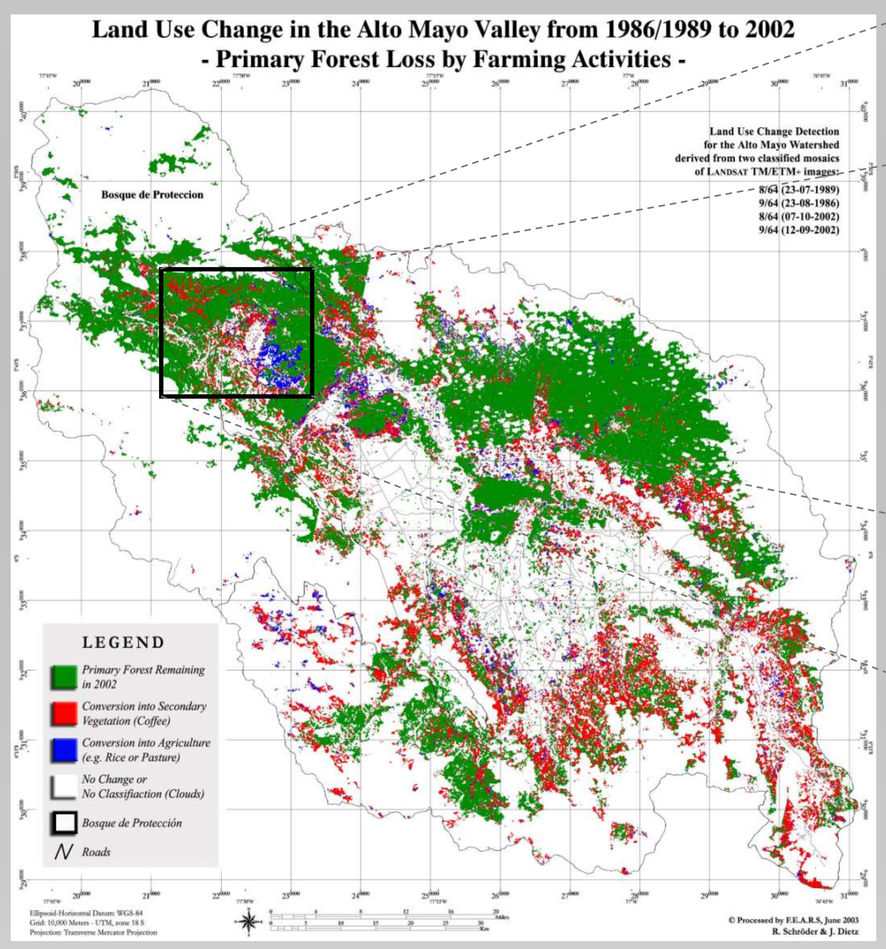



**Fig. 4:** Primary forest loss due to intensive logging for the reclamation of agricultural land as detected by comparing classifications from 1986/89 to 2002. Heavy cloud cover in the 2002 scenes account for the blank margins and aggravated the drawing of conclusions to a complete scale.

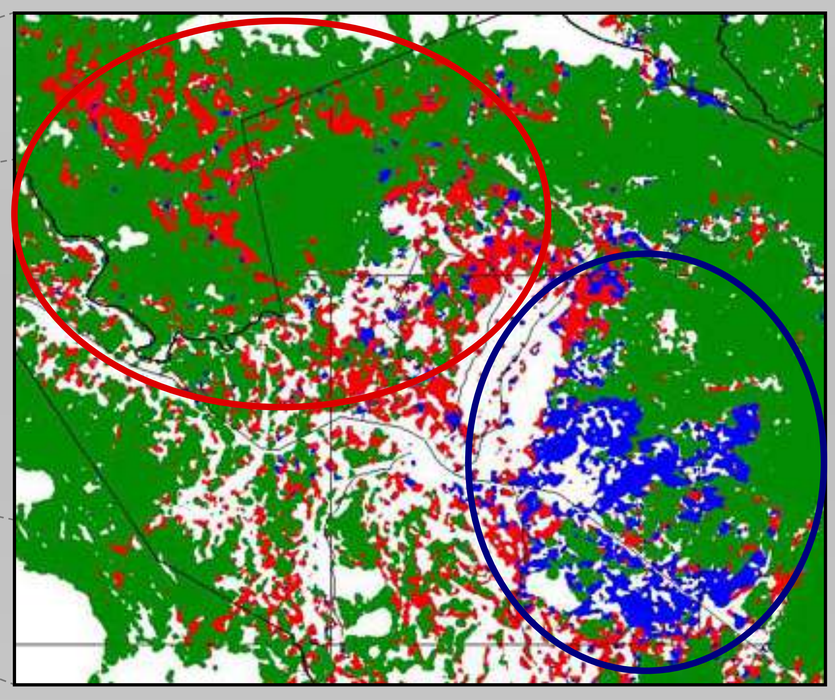


**Fig. 5:** Detail from the northern part of the study area showing forest conversion in detail. Green parts remained forest since the 1980's while red shows conversion to mainly coffee plantations and blue areas have now become rice fields. White areas had already been cleared in the initial stage.

## Classification

Six LANDSAT images (1986, 1989, 1999, 2002) were georeferenced. Atmospheric correction was carried out by dark subtraction prior to cloud and shadow masking. A pair of scenes (8/64 & 9/64) was mosaicked allowing to compensate cloud cover in the overlap area (Fig. 2) to obtain maximum coverage of the 800 000 ha study area (1986/98: 89% , 1999: 66%, 2002: 57%).
During field work, 503 ground truth points were recorded and initially assigned to 13 classes. Cross-checking with an unsupervised classification for 2002 (TM 1,2,3,4,5,6,7,ratios4/3,7/5) yielded eight classes with robust spectral signatures. These were entered into a supervised classification. Due to technical image inconsistencies, the older scenes were processed similarly, yet based on less ground truth data.

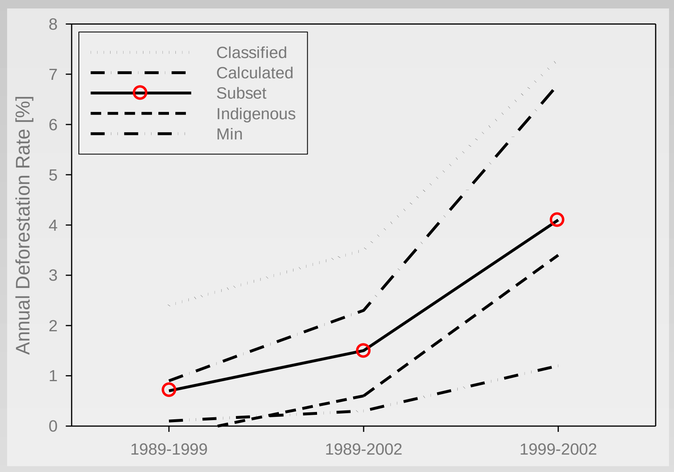



**Fig. 6:** Annual deforestation rates for all scenarios and for the management by the indigenous population. The most likely estimation is based on a representative cloudless **subset** of the study area

**Tab. 1:** Land use change between 1986/89 and 2002 obtained from a cloudless subset of the valley bottom. Percent values refer to the initial state in 1986/89, where urban areas were frequently misclassified due to the lack of the thermal infrared band TM6 in that image. This explains the high turnover in the urban area class.

| 1986/89 / 2002 | Primary Forest | Secondary Vegetation | Abandoned / Pasture | Open Soil / Alpine Grass | Rice | River / Rice | Urban Areas | Total Area 1986/98 [ha] |
|---|---|---|---|---|---|---|---|---|
| | % | | | | | | | |
| **Primary Forest** | **74.9** | 14.7 | 4.1 | 1.9 | 3.3 | 7.3 | 6.7 | 48196 |
| **Secondary Vegetation** | 17.8 | **58.0** | 47.9 | 51.1 | 23.3 | 11.2 | 21.3 | 4557 |
| **Abandoned / Pasture** | 2.3 | 2.5 | **1.6** | 2.8 | 2.1 | 0.3 | 4.6 | 1053 |
| **Open Soil / Alpine Grass** | 3.0 | 11.8 | 12.8 | **22.4** | 9.4 | 1.4 | 16.6 | 2083 |
| **Rice** | 1.1 | 7.3 | 21.7 | 11.7 | **24.7** | 4.8 | 15.2 | 386 |
| **River / Rice** | 0.7 | 5.3 | 11.8 | 9.2 | 36.6 | **75.0** | 27.5 | 613 |
| **Urban Areas** | 0.1 | 0.4 | 0.1 | 0.9 | 0.7 | 0.0 | **8.2** | 200 |
| **Total Area 2002** [ha] | 36945 | 13039 | 1341 | 2675 | 1519 | 1544 | 87 | |

**Tab. 2:** Deforestation rates (absolute decrease: *Rate*; relative increase: *Area*) for three different time periods indicating an upward trend in recent years (cf. Fig. 6).

| Deforestation | 1989 - 1999[1] | | 1989 - 2002[1] | | 1999 - 2002[1] | |
|---|---|---|---|---|---|---|
| | Rate[2] | Area[3] | Rate[2] | Area[3] | Rate[2] | Area[3] |
| | % | | | | | |
| Classified* | 2.4 | -3.6 | 3.5 | -5.3 | 7.3 | -17.3 |
| Calculated** | **0.9** | **-1.3** | **2.3** | **-3.1** | **6.8** | **-10.4** |
| Subset*** | **0.7** | **-0.9** | **1.5** | **-1.8** | **4.1** | **-5.4** |
| Indigenous | **-0.2** | **0.3** | **0.6** | **-0.7** | **3.4** | **-3.7** |
| Min**** | 0.1 | -0.1 | 0.3 | -0.4 | 1.2 | -1.5 |

[1] = assuming a linear behavior
[2] = reference: the total Alto Mayo watershed / subset
[3] = reference: area covered by primary forest in the initial state


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