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

F.E.A.R.S.

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Motivation

Clearing of pristine forests for rice and coffee cultivation 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). As a secondary effect to the rice cultivation activities in the valley, adjacent hill areas and the steeper valley slopes are now cleared for coffee cultivation.

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 satellite imagery based analysis on the rate of land conversion for the entire Alto Mayo region.

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.

To test the hypothesis that primary forest conversion is less pronounced under traditional management by Comunidades Nativas, the cloudless portion (44.4%) of the 150 000 ha ascribed to CNs was investigated (Tab.2). Overall trends are similar, but primary forest loss and the proportion of rice cultivation were lower than under conventional management by Peruvian settlers.

Deforestation

In the Alto Mayo valley, cloud cover concentrates at the remote mountain ranges which still retain much of their original forest cover. Since these areas can not be image classified, we have developed several scenarios based on different reference systems (Tabs. 3 & 4). The margin between such a minimum and a maximum scenario is demonstrated in Fig. 6.

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%. Most of the primary forest along the sloped forest fringes is now converted into coffee plantations. The valley plains are suitable for rice cultivation and had already been cleared in the early 1980's (Figs. 4 & 5).

Conclusions

Forest and land management by indigenous tribes is still a slightly more conservationist approach. However, forest conversion in Comunidades Nativas (CN) has increased in recent years and their deforestation rates are likely to 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.

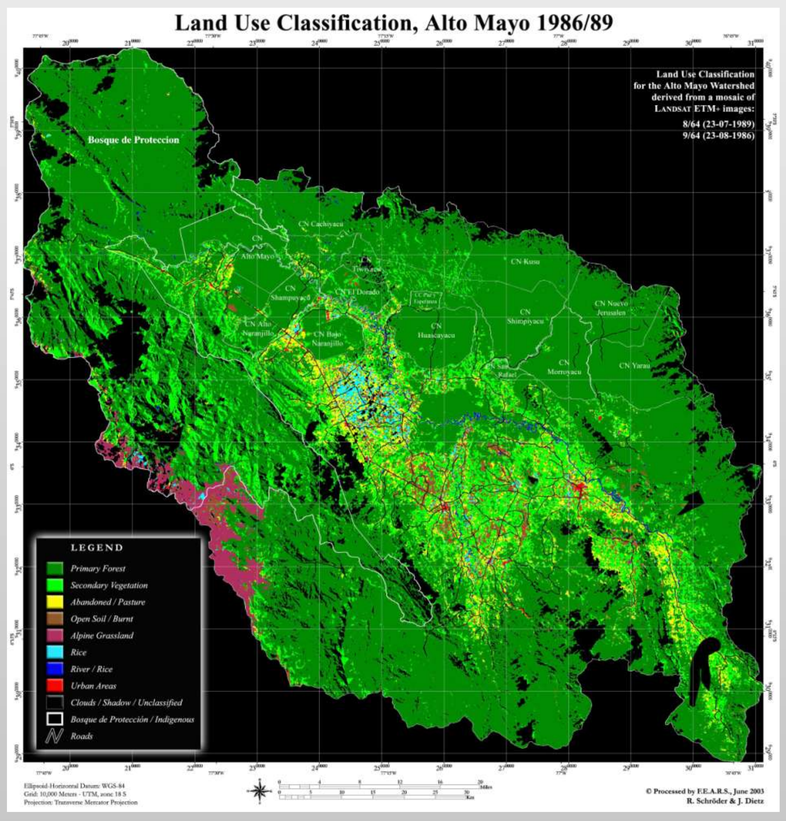
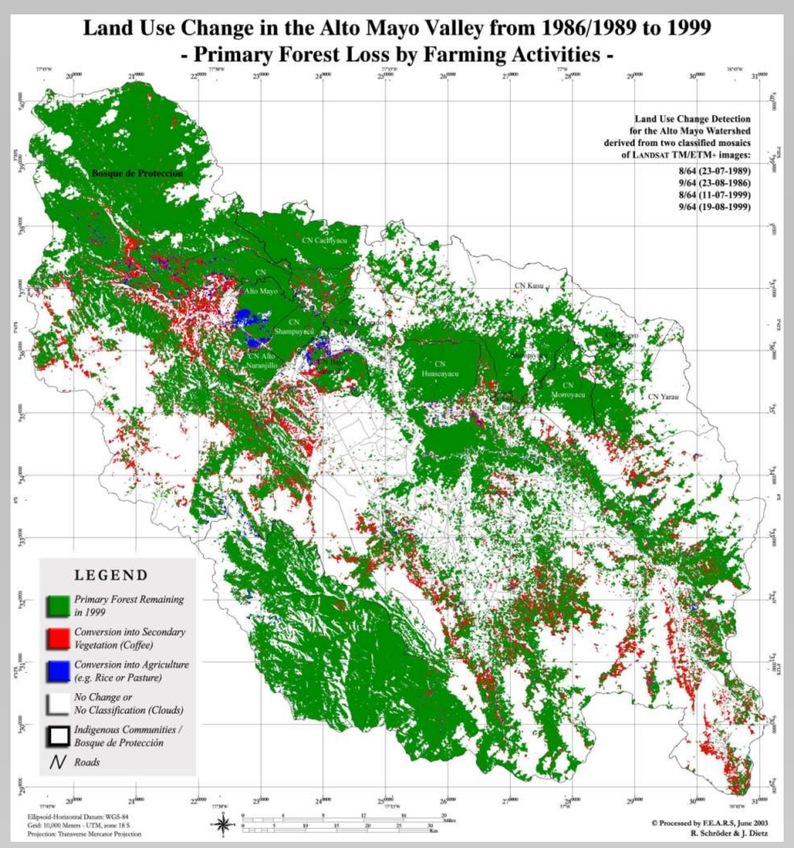
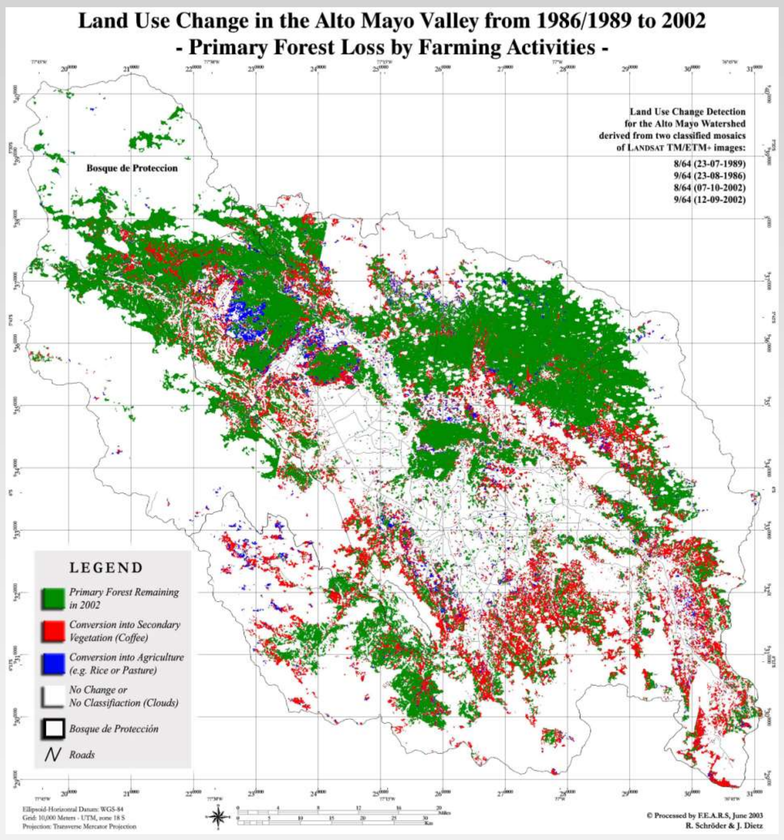


Fig. 3 Result of a hybrid classification of the LANDSAT TM mosaic from 1986/89 (Fig.2) picturing the initial reference state for the following land use change observations. Outlined are actual and projected roads as well as the boundaries of indigenous community estates and a local forest sanctuary ("Bosque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



Figs. 4⇧ & 5⇩: Primary forest loss due to intensive logging for the reclamation of agricultural land as detected by comparing classifications from 1986/89 to 1999 and 2002, respectively. Heavy cloud cover in the 1999 and 2002 scenes aggravated the drawing of conclusions to a complete scale.



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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).

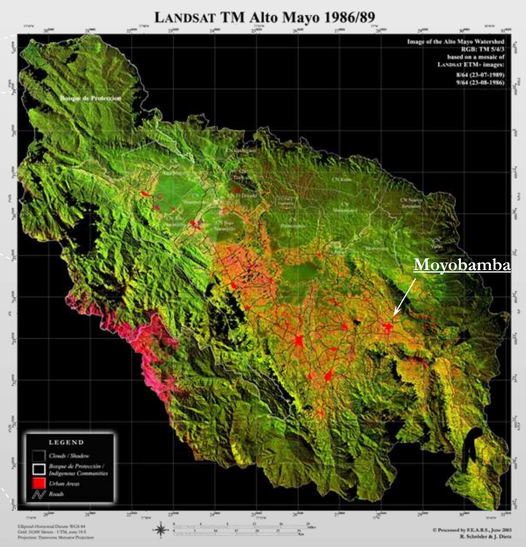


Fig. 2: Original LANDSAT TM mosaic (RGB: TM 5/4/3) from 1986 (west) and 1989 (east) after cloud masking. Significant differences in topographic illumination are conspicuous. Elevations range between 600 and 4 500 m a.s.l..

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 leads to a high turnover in the urban area class.

2002 \ 1986/89	Primary Forest	Secondary Vegetation	Abandoned Pasture	Open Soil Burnt	Rice	River / Rice	Urban Areas	Total Area 1986/89
	%							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 Meadow	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**
Class Change	**25.1**	**42.0**	**98.4**	**77.6**	**75.3**	**25.0**	**91.8**	
Total Area 2002 [ha]	**36945**	**13039**	**1341**	**2675**	**1519**	**1544**	**87**	

Tab. 2: Land use change between 1986/89 and 2002 for unclouded areas under indigenous control. Due to high cloud cover over these regions especially at higher elevations the classification may overestimate the land affected by human influence. The high turnover in the urban area class is again due to the lack of the thermal infrared band in 1986/89.

2002 \ 1986/89	Primary Forest	Secondary Vegetation	Abandoned Pasture	Open Soil Burnt	Rice	River / Rice	Urban Areas	Total Area 1986/89
	%							ha
Primary Forest	**84.0**	19.2	6.9	2.0	9.1	24.1	3.7	**63800**
Secondary Vegetation	11.8	**61.2**	42.6	45.5	35.0	11.8	35.4	**2557**
Abandoned / Pasture	1.2	3.8	**6.1**	8.6	1.6	1.0	2.2	**46**
Open Soil / Alpine Meadow	1.3	7.0	25.0	**21.0**	6.9	0.3	16.4	**425**
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Urban Areas	0.0	0.4	0.0	1.1	0.8	0.2	**0.1**	**78**
Class Change	**16.0**	**38.8**	**93.9**	**79.0**	**78.7**	**40.3**	**99.9**	
Total Area 2002 [ha]	**54163**	**9392**	**916**	**1107**	**1069**	**423**	**28**	

Tab. 3: Changes of primary forest cover classified for the years 1986/89, 1999 and 2002 using four different scenarios to compensate incomplete information due to heavy cloud cover. It also includes the situation under indigenous management.

Primary Forest	1989		1999		2002		Δ area / 10 years		Δ area / 13 years		Δ area / 3 years	
	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
Classified*	528716	66.1	340043	42.5	163683	20.5	188673	23.6	365033	45.6	176360	22.0
Calculated**	593838	74.2	519398	64.9	357000	44.6	74440	9.3	236838	29.6	162398	20.3
Subset***	48196	84.4	44040	77.1	36945	64.7	4157	7.3	11252	19.7	7095	12.4
Indigenous	59519	88.7	61019	91.0	54163	80.7	-1500	-2.2	5356	8.0	6857	10.2
Min****	616474	77.0	611592	76.4	583718	72.9	4882	0.6	32756	4.1	27874	3.5

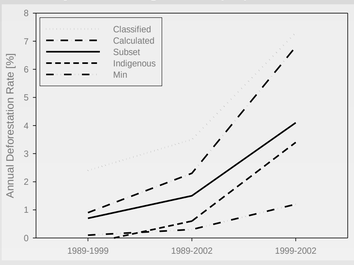
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Tab. 4: Deforestation rates (absolute: *annual rate*; relative: *decrease*) for three different time periods indicating an upward trend in recent years.

Deforestation	1989 - 1999[1]		1989 - 2002[1]		1999 - 2002[1]	
	Annual Rate[2]	Decrease[3]	Annual Rate[2]	Decrease[3]	Annual Rate[2]	Decrease[3]
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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
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Fig. 6: Annual deforestation rates for all scenarios and for the management by the indigenous population.



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.

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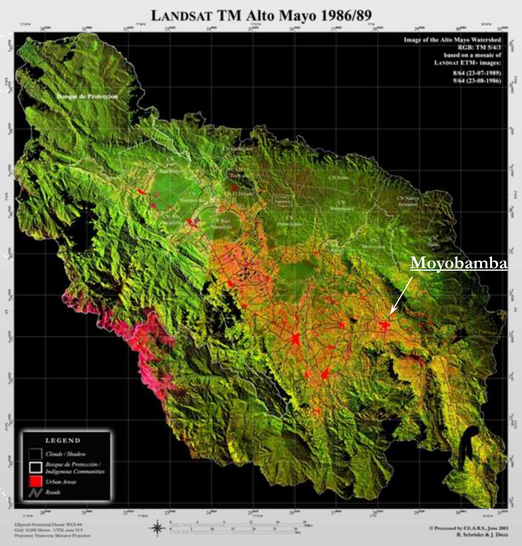


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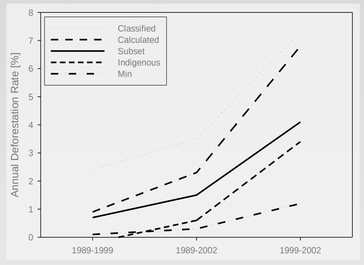
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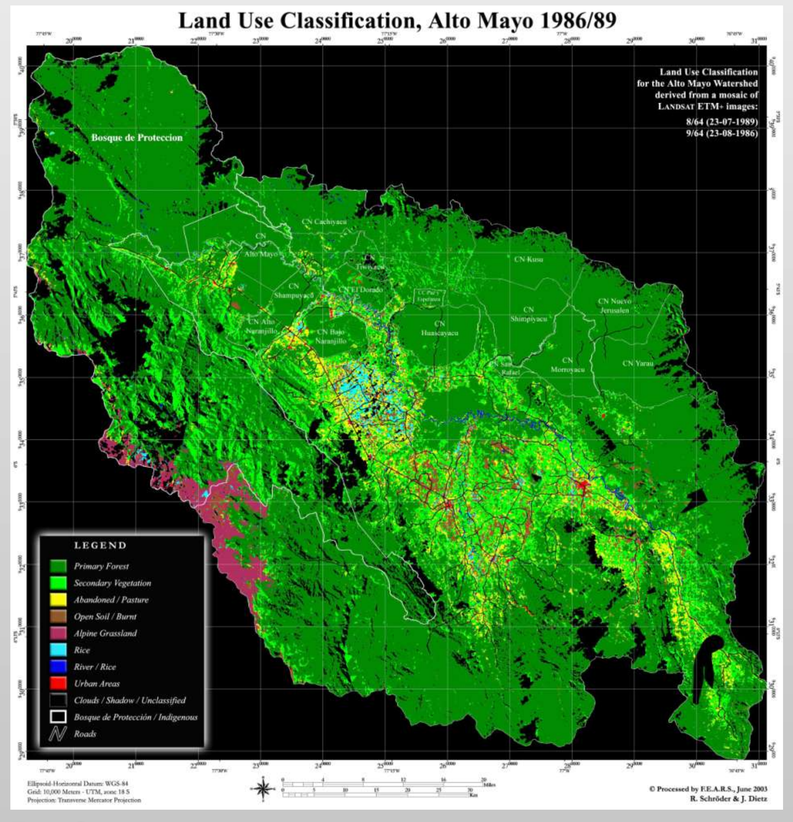
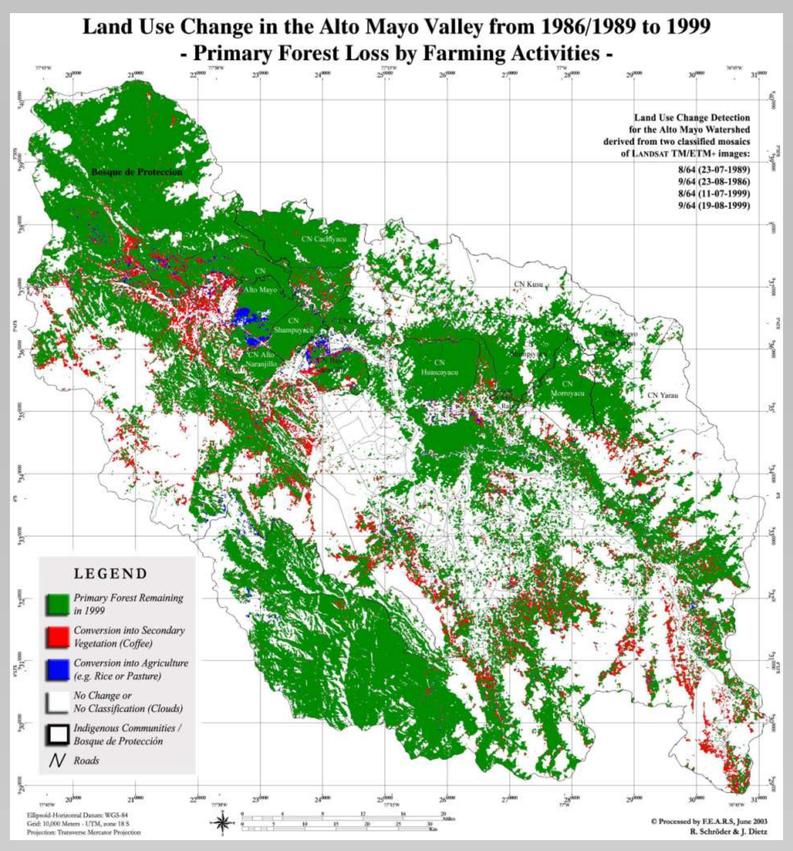
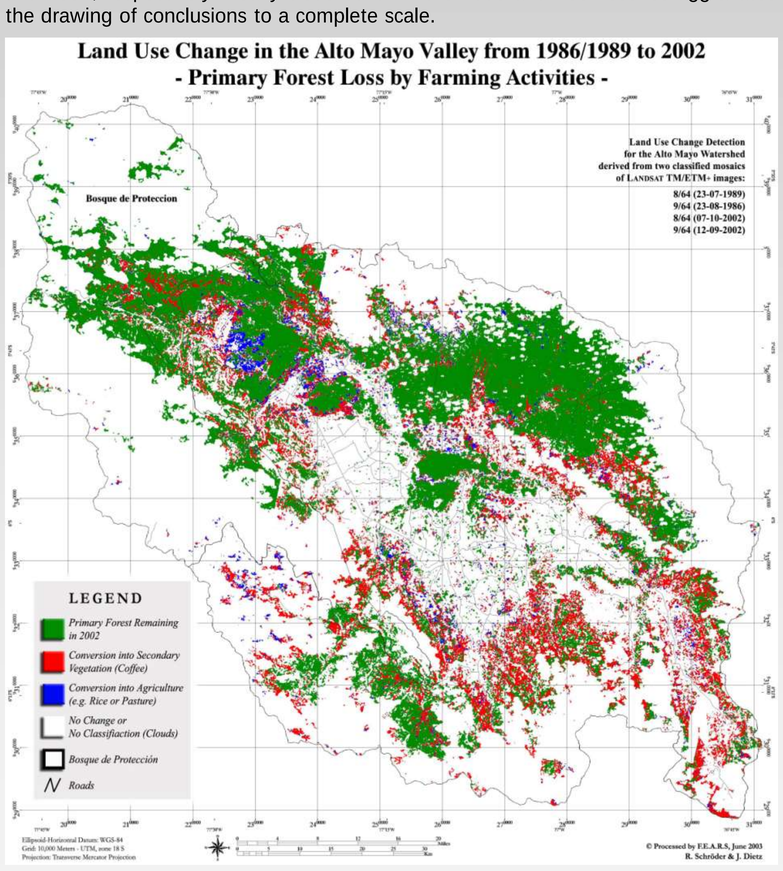


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