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Global meat consumption trends and local deforestation in Madre de Dios: assessing land use changes and other environmental impacts

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Abstract

Meat consumption is becoming one of the most relevant sectors in terms of environmental impacts globally. In the Brazilian Amazon the effects of this process are seen in the ongoing deforestation and land-use change (about 65% of deforestation can be linked to cattle ranching). One of the main causes of this trend is the increased efficiency of the transport infrastructure: along both sides of the Brazilian Inter-Oceanic highway, about 50km of rainforest have been converted to cattle ranching. In 2011 the Inter-Oceanic highway was finalized also on the Peruvian side: the region of Madre de Dios is neighboring the Brazilian Amazon, therefore the risk is that this area will undergo the same kind of development.

The objective of this analysis is to highlight the contribution of global meat demand trend as cause of land use change and deforestation in the Madre de Dios region. This focus has been chosen since, nowadays, the magnitude of cattle ranching activities is hidden by more evident and damaging activities (e.g., gold mining), and its near-future effects risk to be underestimated. By starting with investigating the preliminary signals of cattle ranching contribution to the local deforestation process, this analysis will serve as basis for more comprehensive future works on local data, including monitoring campaigns of local biodiversity and GHG emissions. Land-use change is, thus, analyzed through FAO data and also through data acquired with remote sensing carried out within other projects. Meat consumption and production outcomes are obtained from the FAOSTAT database. By integrating trends in the regional meat consumption with the emerging trading effects, which are incremented by the new highway, it is possible to highlight the risk that the global convergence in meat consumption trends can locally influence the deforestation in Madre de Dios.

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Keywords: Global meat consumption; Deforestation; Land-use change; Inter-Oceanic highway;

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1. Introduction

The increasing meat demand at the global level has been emerging as one of the causes of global environmental issues like climate change and deforestation, due to the related intensive cattle ranching activities. The Amazon rainforest is one of the most damaged ecosystems by cattle ranching: in particular, in the last decade the deforestation due to these intensive activities has been evident along the Brazilian layout of the Inter-Oceanic highway. After the finalization of the Peruvian part of the same highway, also the areas of Amazon forest in the Peruvian regions which are crossed by this infrastructure risk to undergo the same damages that have taken place on the Brazilian side. Nevertheless, in the Madre de Dios region this risk could be hidden by more prominent and damaging phenomena, like gold mining. Given this threatening risk, we analyze the meat consumption trends in Peru and South America and compare them with the global ones. Consequently, we carry out a preliminary evaluation of the land-use changes in the area, focusing on deforestation and transformation (highlighting permanent pasture and meadows evolution), using open-source data, since nowadays we do not have specific field data available. Thus, this paper aims at highlighting the likely risk that global meat consumption trends could affect the future deforestation process in this specific region.

1.1. Meat consumption trend in the world

In the near future the role of the food system in driving the environmental change on a global level will increase significantly. This is due mainly to two factors: in the first place, the need for food will expand as population will continue to grow [2]; in the second place, income per capita will also rise, and this has traditionally led to a higher consumption of animal protein, fats and sugars [3]. Thus, both the food system and the ecosystems on which it depends will be challenged significantly [4]. The current need is for a way to produce food which accounts for the environmental externalities, while ensuring that the growing global population has a nutritionally correct food supply [5]. The food system of the future should be both resilient and sustainable from the environmental point of view, but with an increased efficiency. As the food sector with the highest impact is that of animal products, it is possible to get a comprehensive picture of the current food system by analyzing three main indicators: land requirement for animal products, meat consumption per capita and the amount of animals slaughtered per capita.

In 2007 the total area harvested for animal products achieved 440 million hectares, while the average global land requirement for animal products per capita was equal to 610 square meters [6]. The meat consumed per capita in 2009 globally was 41 kilograms, which corresponds to a total of nearly 280 Mt of meat globally [1].

The number of animals slaughtered is also significant: in 2009 over ten animals were slaughtered per capita, which translates to almost 63 billion animals (i.e. chickens, pigs and cattle) slaughtered in total (own calculation, data from FAOSTAT). When looking at the evolution of these three indicators in the last 50 years, it is evident that the growth rates for all the Asian countries together with Central and Southern America are much higher than the world average [7]. Such pattern is a consequence of the significant economic development that has occurred in these regions. It is clear that poultry has become more and more relevant globally (values have increased about five times in 50 years), and also that meat consumption is becoming more important in most regions of the world, especially in those undergoing rapid economic growth [7]. It can be said that diets are converging globally in terms of meat consumption, a trend which puts a considerable stress on the environmental resources available globally, including the Amazon forest.

1.2. Amazon deforestation and meat consumption

The Amazon is the largest tropical forest in the world (6 million km^2) and its basin covers nine countries within South America. The deforestation of this rainforest has been very noticeable during the last 40 years due to human activities, and continues intensely [8]. Between 2004 and 2011, the Terra-i monitoring system (the only land-cover change monitoring system available that provides satellite based rainfall and vegetation data with consistent spatial -250m- and temporal resolution -6 days- for the entire of Amazon) detected a cumulative habitat loss of 14,159,913 hectares across the nine countries. Eighty-eight percent of the detected land cover change occurred in moist forest.

The main causes of this prominent land-use change are the demand for firewood, mineral exploitation, the cultivation of illicit crops and forest fires (some caused by practices such as slash-and-burn), but the key drivers have been monocultures and cattle-ranching [9]: their expansion results from the growing global demand for agricultural commodities [8]. In addition, the construction of highways (e.g., infrastructures implemented by the Initiative for the Integration of the Regional Infrastructure of South America, IIRSA) is a crucial factor, which magnifies the influence of other drivers on land use change. In effect, "*the deforestation by shifting cultivation and livestock is directly related to the accessibility of forested lands. Therefore, the road can be considered as an*

enabler that eases access to remote areas and therefore has a considerable negative impact within its area of influence (between 0 km and 50 km from the road)" [10].

Focusing on Peru, the Peruvian Amazon covers 60% of the territory of which roughly more than two-thirds is forested (53.1% of entire country) [2]. According to the latest GEO Amazon Report, the total cumulative area deforested by 2005 in Amazon basin was 85,766,600 million ha, and of this total area deforested about 9% occurred in Peru. Moreover, a study of [11] estimated the deforestation for the year 2010, 2020 and 2030 in Peru. It results that in 2010 almost 5% of forest cover has been removed, and according to the model, an equivalent amount of deforestation will occur in just 20 years, and by 2030 the Peruvian Amazon would lose 10% of its forests. Concerning the causes, the Ministry of Environment of Peru identifies agricultural expansion as the main direct cause of deforestation in Peru [12]. Agriculture in the country is based on slash-and-burn system used by settlers for subsistence purposes, which affects soil fertility and let the settlers move to another place to start again with the same method [12]. Beside the shifting cultivation, other direct drivers are infrastructure construction (e.g., road), hydropower projects and hydrocarbon and minerals exploitation [11].

1.3. Madre de Dios: ArBio and its land concession

ArBio, Association for Resilience front of the Inter-Oceanic Highway, was born from the need to change the current patterns of development in the Amazon towards a sustainable development model, in which humans can coexist with forest ecosystems, without the need to turn it into a vast flat monoculture. ArBio operates in the Department of Madre de Dios (Peru), in the bordering area with the region of Pando (Bolivia) and Acre (Brazil).
This Amazon region is now also interrupted by the third section of the southern Inter-Oceanic highway, at 20 km from our base area. The construction of the new Inter-Oceanic highway in the Madre de Dios opens the door to a big threat: large-scale investments in agriculture and the subsequent deforestation of 50 km on both sides of the road 20 years after its construction (that is what has happened in the Brazilian side of the same Highway). In fact, from Figure 1 (resulting from a preliminary analysis on land concessions in the area) it emerges that along the highway all the patches (pink ones) are the deforested or used for agricultural purposes: the outcome obtained through the reported analysis consists in the starting point of this work.

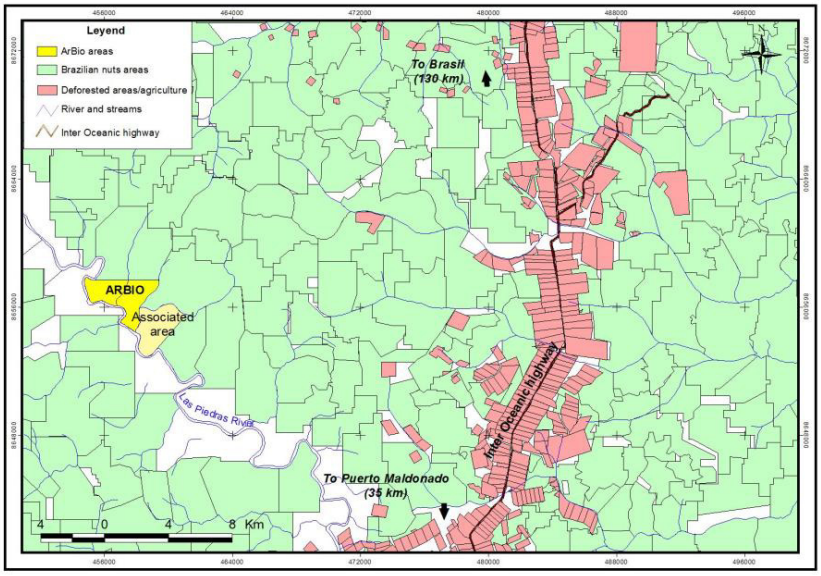

Figure 1: Land concessions in Madre de Dios region: cadastral data (ArBio elaboration)

Since the region has one of the greatest biodiversity rates on the planet, including the world record in number of species butterflies, ArBio's goal is to protect it, preserving the structure and function of forest ecosystems. By focusing on economically viable and sustainable solutions for the Brazil nut gatherers in the region, such as Analog Forestry, small-scale Agro-forestry, ArBio aims at creating a buffer to stop or contain deforestation around the road.

1.4. Objective

The objective of this work is to create the basis for a deeper investigation of the possible future land-use change trends in Madre de Dios region and the related effects. In particular, we aim at highlighting the main causes and risks influencing the forest loss in this area, among which we decided to focus on cattle ranching activities. This choice is mainly due to the fact that the magnitude of cattle ranching near-future effects on the deforestation process risk to be underestimated, because they are nowadays hidden by other devastating causes like gold mining. Moreover, the intensive agricultural activities belonging to the meat supply chain have been indicated as one of the major drivers for the land-use change in Amazon, especially in the Brazilian part. We chose the Madre de Dios area for two main reasons: firstly because this region is one of the most affected by deforestation in the last years and the future risk is even higher due to the presence of the Inter-Oceanic highway, and secondly, because we are able to directly operate on the region through the ArBio land concession. Finally, as it was previously stated, the long-term goal of this study is to organize monitoring campaigns (i.e. data collection) in the area, in order to preserve the rich biodiversity in Madre de Dios.

2. Materials and methods

Two main parts compose the analysis implemented in this study. The first includes the assessment of meat trends, and was carried out using FAO data [1]. Specifically, we use the data series for production (metric tons), food-supply quantity (both total metric tons and kilograms per capita) and import-export flows for bovine meat, pig meat, and poultry. The geographical areas involved in this analysis are the world, South America and Peru. In the FAOSTAT database, meat supply is defined as carcass weight (including bones and excluding the parts not suitable for human consumption) and takes into account the losses that occur from production to household [13]. After assessing evolution and trends characterizing the time series involved, and comparing the different geographical areas, an indication of how much dependent Peru and South America are in terms of meat procurement is quantified, considering the imports of meat from other countries: by dividing the imports by the corresponding food supplies, we can thus calculate the ”meat dependency” ratio of a region for different kinds of meat.

The second part concerns land-use change and deforestation, which are analyzed by taking into account different sources. The first one is the FAO database [1], which was already used for the previous analysis, in order to obtain a minimum level of consistency among the results. In this database the forest area is obtained from annual areas of ‘forest land’ provided by the Global Forest Resource Assessment (GFRA) [14] of FAO. GFRA-FAO supplies data concerning ‘Primary forest’, ‘Other naturally regenerated forest’ and ‘Planted forest’ for the years 1990, 2000, 2005 and 2010 for each country. Complete time series for each category, for the period 1990-2010 are obtained through linear interpolation. The categories ‘Primary forest’ and ‘Other naturally regenerated forest’ are then aggregated, while the category of planted forest was considered separately, in order to compute the total forest area at one specific year [1]. Using this dataset the evolution of forest loss and transformation in Peru was assessed and compared with the rest of the world and the rest of South America.

In order to evaluate the reliability of FAO land-use data, a comparison with the satellite-based datasets was made: in particular, the datasets provided by Terra-i project (see paragraph 1.2) and PRODES system [15] were involved. The two systems are compared in [16] (Annex II), and one of the main differences concerns the classification of forest area: PRODES only estimated the changes in the moist forest and not in grasslands and savannas, which are instead considered by Terra-i system; this discrepancy results in different values of the total forested area.

Finally, a focus on the Madre de Dios region was made. Terra-i data resolution permits to have specific data on the forest area in the region for the period 2004-2011. After presenting these data, a qualitative analysis was performed using the web-based visualization tool [17] created by the Department of Geographic Sciences of the University of Maryland: it analyzes and displays data provided by Hansen et al. [18]. In particular, it displays results coming from the analysis of Landsat time-series and deriving images, which characterize forest extent and its changes. Different time series are analyzed. In particular, ‘2000 Percent Tree Cover’ regards the area covered by trees, which are defined as “*vegetation taller than 5m in height*”, and the related area is expressed as a percentage per output grid cell. ‘Forest Cover Loss’ is defined as a stand-replacement disturbance, or a change from a forest to non-forest state, during the period 2000–2013. ‘Forest Loss Year’ is a disaggregation of total ‘Forest Loss’ to annual time scales. ‘Reference 2000’ and ‘Reference 2013’ imageries are median observations of a set of quality assessment-passed

growing season observations. Some qualitative considerations are derived from the maps observations and their integration with the map regarding land concessions in the region produced by ArBio (Figure 1).

3. Results

3.1. Evolution of meat consumption and production

As mentioned above, meat consumption has risen steadily in the last 50 years at the global level, with poultry and pig meat covering the most significant role. In the case of South America, poultry shows the most remarkable growth in the last 20 years, but the production of cattle has increased steadily throughout the time series. This is due to the growing importance of its exports, especially within the last 10 years of the period analyzed. The amount of cattle meat exported from South America has increased more than four-fold since the '60s, reaching the value of 1,350,090 metric tons in 2011 [1]. In the specific case of Peru, the production of poultry meat is over 5 times greater than that of pig and bovine meat, with the latter two increasing slightly during the last 15 years of the period analyzed. The production of poultry meat has expanded greatly during the last 20 years, reaching the amount of 1,171,470 metric tons in 2012 [1].

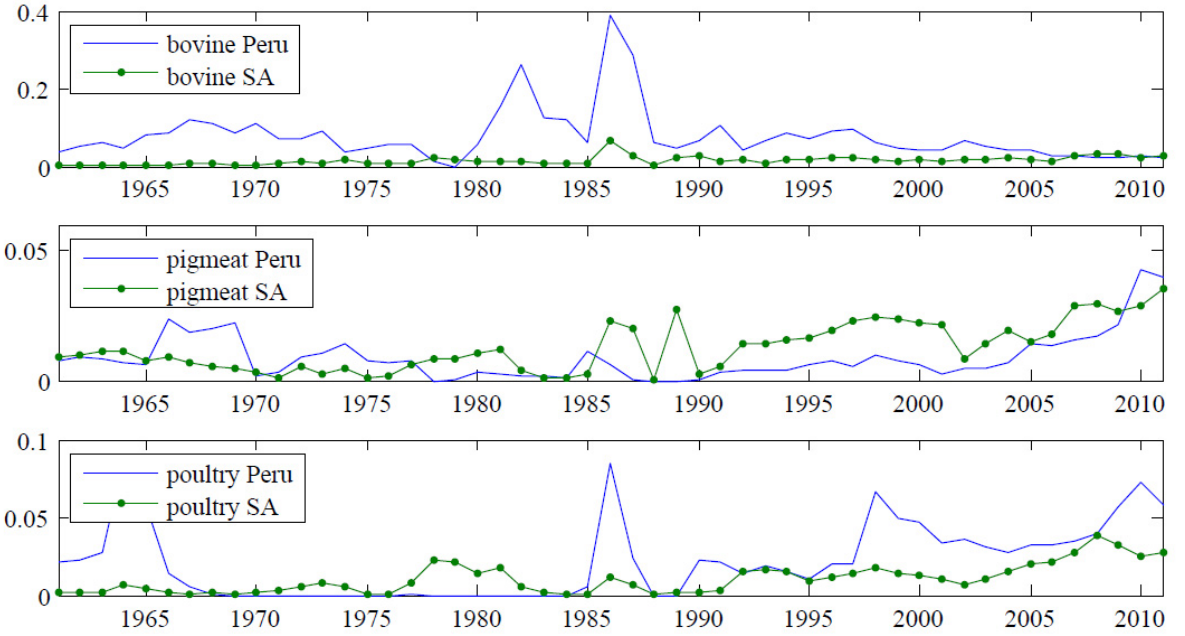

Figure 2: 'Meat dependency' ratio for bovine, poultry and pig meat in Peru and South America obtained as the ratio between imported meat and food supply (meat)

When comparing the imports of these three main types of meat with their food supply, it is possible to define how dependent the considered region is on the imports of meat from other countries (Figure 2). In the case of bovine meat, both South America as a whole and Peru show a good degree of independence, with values of dependency lower than 10% in most cases. The only exception is in the case of Peru in the '80s, when there were peaks of dependency over 35%; however, the situation is very different nowadays, with a dependency for bovine meat lower than 5%. For pig and poultry meat, the situation is similar for both South America and Peru, with an increasing dependence in the last 15 years which, however, remains equal to few percentage points.

3.2. Land-use change and deforestation

Table 1 shows data about forest area in the world, in South America and in Peru (both in 1990 and 2012), from which a comparison between 1990 and 2012 is derived [1].

Table 1: Data of forest area (1000 ha) and its variation between 1990 and 2012 in Peru, South America and the whole world

	Forest area (1000 ha)		1990 VS 2012	
AREA	1990	2012	1000 ha	%
World	4,168,400	4,021,910	-146,490	-3.5%
South America	946,454	857,188	-89,266	-9.4%
Peru	70,156	67,692	-2,464	-3.5%

The deforestation has been experienced in the three "areas" considered (see Table 1): South America is characterized by the highest percentage difference between 1990 and 2012 (-9.4%), while Peru and the whole World have both a lower percentage rate (-3.5%).

From the same dataset, annual forest loss rate are obtained. The diagram in Figure 3 shows that in 2005 the annual deforestation rate in Peru increases abruptly, even if the average rate in South America decreases.

Focusing on Peru, the land-use transformation of the lost forest area can be investigated considering the complete land-use dataset provided by the FAOSTAT database [1]. From the results illustrated in Table 2 it emerges that about 35% of deforested area† (corresponding to the 881 ha lost between 1990 and 2012) became 'Permanent meadows and pastures'. Since this category is defined as "*the land used permanently (five years or more) to grow herbaceous forage crops, either cultivated or growing wild (wild prairie or grazing land).*" [1], it can be directly linked to livestock activities like cattle ranching.

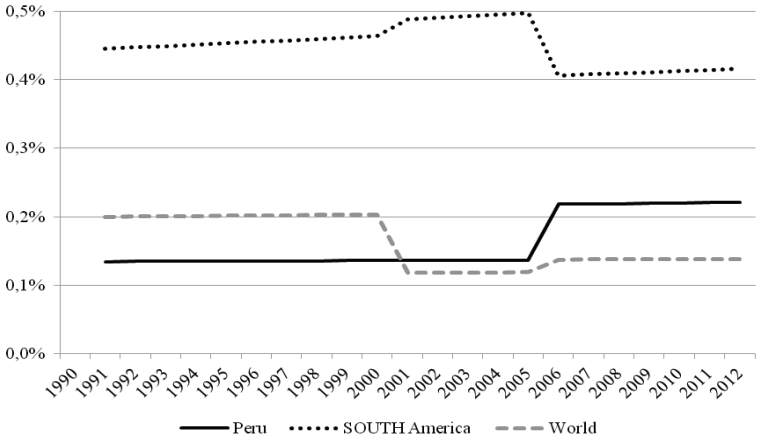

Figure 3: Annual forest loss rate (calculated using FAOSTAT data from 1990 and 2012)

Table 2: Land-use in Peru (FAOSTAT): variation between 1990 and 2012

Land-use category	**(1000 ha)**		**1990 VS 2012**
	1990	2012	(1000 ha)
Arable land	3500	4150	650
Permanent crops	420	1379	959
Permanent meadows and pastures	17916	18797	881
Forest area	70156	67692	-2464
Other land	36008	35982	-26

As a further step in analyzing the forest loss in Peru and in the Madre de Dios area, the land-use data supplied by FAO are compared and integrated with two other published data (Table 3): the remote sensing data collected within the Terra-i project (see paragraph 1) reported in [16] and data reported by [15].

Table 3: Forest area and deforested area in 2011 in Peru: comparison among different sources (reported data are expressed in ha); the columns named with '%' show the percentage ratio between the deforested area and the remaining forest area in 2011 in Peru.

Killeen data (Amazon forest)	Terra-i data (Amazon forest)	FAOSTAT data (forest, non specified)

† The term deforested area' is adopted because 99% of land-use losses (2,464,000 ha out of 2,490,000 ha) belong to the category named 'Forest' and, moreover, the category 'Other land' (which experienced a decrease, too) includes also 'other wooden land' ("*it is the land not classified as Agricultural land and Forest area. It includes built-up and related land, barren land, other wooded land, etc*")

Area (ha)	Deforested area in 2011	%	Area (ha)	Deforested area in 2011	%	Area (ha)	Deforested area in 2011	%
76,404,649	180,004	0.24%	90,698,801	133,269	0.15%	67,842,000	150,000	0.22%

Even though the forest areas have different values (due to the different classification models adopted, see paragraph 2), the annual forest loss rates in 2011 result comparable, ranging between 0.15% and 0.24%. On the other hand, in comparing the trends in annual forest loss between 2004 and 2011 obtained using Terra-i [16] and FAO [1] data, a not negligible difference emerges: according to Terra-i, the outcomes show that 17,038 ha were lost in 2004, reaching 133,269 ha in 2011, with an increase of 682%; if FAOSTAT data are used, the trends show that 94,200 ha were lost in 2004, reaching 150,000 ha in 2011, with an increase of 59%. The dataset and the land-use classification methods should be deeper investigated in order to explain this discrepancy.

The analyzed time series all end in 2011 (except for FAOSTAT dataset, but 2012 data are obtained through a linear interpolation), and it is not possible to verify the peak in forest loss of about 250,000 ha occurred in 2012, which has been reported by Mongabay website obtained using [18] and Global Forest Watch data.

Focusing on Madre de Dios department, the annual forest loss rate in 2011 obtained using Terra-i data results lower than the one referred to the whole Peru (0.09% and 0.15% respectively, see Table 4).

Table 4: Forest area and deforested area in 2011 in Madre de Dios resulting from Terra-i (reported data are expressed in ha); the columns named with '%' show the percentage ratio between the deforested area and the remaining forest area in 2011.

	Terra-i data		
AREA	Area (ha)	Deforested area in 2011	%
Madre de Dios	8,325,694	7,888	0.09%

Since in Madre de Dios region the Inter-Oceanic highway was opened in July 2011 and it is the only paved road in the region, a preliminary and qualitative analysis on its possible effects on forest loss is done. According to [16], deforestation in Peru occurs both due to cultivation shifting and the opening of more roads for logging, which enables the arrival of farmers. Moreover, an adaptation of [19] results made by Mongabay shows the negative relationship between deforestation and the distance to roads – there is significantly more deforestation in areas easily accessible by road.

Using the web-based visualizations of Hansen et al. [18] data, created by the department of Geographical Sciences of Maryland University [17], and focusing on Madre de Dios area, some preliminary outcomes can be obtained. Firstly, selecting dataset named 'Forest cover loss 2000-2013 (transparent)' on the analyzed region [20], it clearly emerges that the deforestation in the last years mainly occurs along the new highway. Secondly, observing the map obtained selecting the layer 'Forest Loss Year (2012 Highlight)' the forest loss occurred between 2012 and 2013 is sizeable [21]. Moreover, referring to the (Figure 1) realized by using cadastral data, it is confirmed that the concessions directly connected to the highway are deforested and moreover mainly dedicated to agriculture (i.e. cattle ranching and monoculture). Furthermore, these considerations can be integrated by the direct deposition of ArBio operators: during the last 4 years, ArBio has experienced illegal logging in its private land concession, together with fire of already deforested land to avoid the vegetation growth and allow intensive agricultural and ranching activities, as well as the building of new roads. In July 2011 the bridge across Madre de Dios River was finished; the Inter-Oceanic highway was thus completed and the Pacific coast linked to the heart of Amazon forest: this allows transportation in the middle of the rainforest and consequently the economic activities (i.e. agriculture) and the exploitation of the available resources, i.e. wood, minerals (e.g. gold and silver).

4. Discussion and conclusion

From the results presented in this work it emerges that the global meat consumption trends, especially the one of bovine meat (whose production is based on intensive and extensive land-consuming agricultural activities), can become a key driver of forest loss phenomenon in Peru and especially in Madre de Dios region. The main reasons can be summarized in the following points:

- The production of meat in Peru is generally increasing. Even though the production of poultry meat is over 5 times greater than that of pig and bovine meat, the latter have been both slightly increasing during the last 15 years of the period analyzed. Moreover, while meat production in South America is mainly exported, the statistics concerning Peruvian situation don't lead to classify this country as an 'exporter'. The national increase in meat demand, especially concerning bovine meat which is the most land-consuming, is completely satisfied by national production. This increase in meat demand is mainly due to population growth, and its ongoing growth is mainly due

to both the continuous population growth and to changing in diet [6]. This possible evolution can highly affect the future Peruvian forest loss.

- From the analysis of land-use change in Peru obtained from FAOSAT data [1] it emerges that a considerable part of deforested area (about 35%) between 1990 and 2012 has been converted into permanent meadows and pastures. This category can be directly linked to cattle ranching activities.
- Finally, new roads like the Inter-Oceanic highway in Peru, and especially in Madre de Dios, are attractive in trading and thus economic terms. Along these infrastructures the deforestation is accelerated, and this aspect increases the risk of forest loss in Madre de Dios region: as declared by Mongabay, "*these roads together with unprotected rivers have given rise to a rapidly growing industry of gold mining, which brings with it untold destruction of the Peruvian Amazon. In the last decade, deforestation rates have skyrocketed as gold mining surged 400 percent along the Madre de Dios River in Peru"* [22].

The integration of all these outcomes together with the evidence shown in Figure 1 consists in a clear signal of the high risk in forest loss that could occur in Madre de Dios due to cattle ranching activities: therefore meat production (especially bovine one) seems to be an emerging driver of forest loss in Madre de Dios regions. This risk could be even higher than for the rest of Peruvian Amazon due to the presence of the Inter-Oceanic highway, which connects this area to the Pacific coast and the related trade relationships with developing countries like China, whose meat demand in increasing abruptly. Finally, as stated in the introduction, the outcomes of this work consist in the basis for further and deeper investigation on forest loss in Madre de Dios, and the consequent loss in biodiversity. In particular, one of the main follow-ups is the assessment of the statistical correlation between global meat consumption trends and local deforestation in the region.

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