REB
REVISTA DE ESTUDIOS BRASILEÑOS

e-issn: 2386-4540
https://doi.org/10.14201/reb2019611109121

AUTORES

Joaquim Bento de Souza Ferreira Filho*
jbsferre@usp.br

Peter Poschen**
peter.poschen@gmail.com

* Professor at "Luiz de Queiroz" Higher School of Agriculture of USP.

** Professor in the research group on sustainability and environmental governance at University of Freiburg (Germany).

About Trees and People. What Works for Development, Employment and the Environment in the Brazilian Amazon?

De árboles y personas. ¿Qué funciona en el desarrollo, trabajo y medio ambiente en la Amazonia brasileña?

De árvores e pessoas. O que funciona para o desenvolvimento, trabalho e meio ambiente na Amazônia brasileira?

ABSTRACT:
This paper contributes to the controversy about development models for the Amazon region, using insights from high-resolution macro-economic models. A Social Accounting Matrix for the Amazon forest and a Computable General Equilibrium Model reveal new and surprising facts and perspectives for policy making. Many more people earn their livelihood from forests in the Amazon than previously thought. Over 525,000 workers (full-time equivalents) were directly employed in forest products harvesting and processing in 2005, and 115,000 in fishing in rivers. Farming and cattle rearing are bigger employers in the Amazon than forests, but incomes are very low for workers in all three sectors. Those activities are also not better than forestry in terms of stimulating growth. One corollary is that even a zero-deforestation policy to meet Brazil´s climate targets would only lead to 0.62% losses of national GDP accumulated until 2030. The losses would, however, be concentrated in the agricultural frontier and in low skilled workers and poorer families. This calls for measures to achieve a just transition as stipulated in the Paris Climate Agreement and promoted by the ILO. Policy should stimulate local economic development, building on the high potential of sustainable forest use and river fishing for local value addition. Improvements in the productivity of land-use and labor as well as transformations of related value chains will be paramount to improve incomes and realize the potential of the region to prosper in a green economy.

RESUMEN:
El presente artículo contribuye a la controversia sobre los modelos de desarrollo en la región Amazónica, aprovechando los descubrimientos de los modelos macroeconómicos de alta resolución. Una Matriz de Contabilidad Social para el bosque amazónico y un Modelo Computable de Equilibrio General revelan nuevos hechos y perspectivas para la formulación de políticas. Muchas más personas de lo que se pensaba se ganan la vida en base a los bosques de la Amazonia. Más de 525.000 trabajadores (de trabajo a tiempo completo) encontraron empleo directo en la cosecha y la fabricación de productos forestales en 2005 y 115.000 en la pesca de río. Los cultivos agrícolas y la cría de ganado tienen mayor tasa de empleo en la Amazonia que los bosques, pero los tres sectores ofrecen ingresos muy bajos. Estas actividades tampoco son mejores que la forestal para estimular el crecimiento económico. Un ejemplo de esto es que el coste de una política de deforestación cero para alcanzar las metas brasileñas de cambio climático provocaría pérdidas de solo el 0.62% del PIB nacional acumulado en 2030. Estas pérdidas, no obstante, recaerían en la frontera agrícola, en los trabajadores de baja calificación y en las familias pobres. Esto requiere medidas para lograr una transición justa tal como la estipulada en el Acuerdo del Clima de París, que fue promovido por la OIT. Las políticas deberían estimular el desarrollo económico local, aprovechando el alto potencial del uso sostenible de bosques y de la pesca de río para agregar valor a lo local. El aumento de la productividad del uso del suelo y del trabajo, además de la transformación de las respectivas cadenas de valor, serán fundamentales para mejorar la renta y lograr que el potencial de la región prospere como una economía verde.

RESUMO:
O presente artigo contribui para com a controversa sobre modelos de desenvolvimento para a Amazônia brasileira, aproveitando descobertas de modelos macroeconômicos de alta resolução. Uma Matriz de Contabilidade Social para a floresta amazônica e um Modelo de Equilíbrio Geral Computável revelam fatos novos y perspectivas para a formulação de politicas. Muito mais pessoas ganham a sua vida no uso da floresta amazônica do que se pensava. Mais de 525.000 trabalhadores (equivalentes de trabalho a tempo completo) estavam empregados na colheita y fabricação de produtos florestais e outros 115.000 na pesca de rio. Cultivos agrícolas e a pecuária são empregadores maiores na Amazônia que a floresta, mas os três setores oferecem rendas muito baixas. As outras atividades também não são melhores para estimular o crescimento econômico. Um desdobramento disso é que uma politica de desmatamento zero para cumprir as metas brasileiras de mudança climática provocaria uma perdida de apenas 0.62% do PIB nacional cumulativo ao 2030. Essas perdas, porém, recaem na fronteira agrícola, nos trabalhadores menos qualificados e em famílias pobres. Isso requer medidas para alcançar uma transição justa tal como estipulada no Acordo de Paris sobre o Clima e promovido pela OIT. As políticas deveriam estimular um desenvolvimento econômico local, aproveitando o alto potencial do uso sustentável da floresta e da pesca de rio de agregar valor localmente. Aumentos da produtividade do uso do solo e do trabalho tal como a transformação das cadeias de valor relacionadas serão fundamentais para melhorar renda e realizar o potencial da região de prosperar numa economia verde.

KEY WORDS
Amazon;
Development;
Employment.

PALABRAS CLAVE
Amazonia;
Desarrollo;
Trabajo.

PALAVRAS-CHAVE
Amazônia;
Desenvolvimento;
Trabalho.

Recibido:
24/08/2018
Aceptado:
12/01/2019

1. Introduction

The Amazon appears paradoxical and for decades has been generating very heated and controversial debates about its development. The natural resource endowment of the Amazon makes it very rich. By contrast, its population is among the poorest and least developed in Brazil.

The Brazilian Amazon (the states comprising ´Amazonia legal´) alone has an area of 5 million km^2. It is home to one third of all tropical forest, harboring at least 20 percent of global biodiversity including over 16,000 species of trees (Imazon, 2014; World Bank, 2018). The catchment area contains one fifth of all freshwater as well as very substantial deposits of minerals.

Yet, with nearly 60 percent of the territory of Brazil and 13 percent of its population, the Amazon only generates 8 percent of the country´s GDP. Of its 24 million inhabitants, 43.1 percent live on less than US$ 5.5/day compared to a national average of 25.4 percent (IBGE, 2017). Similarly, considering development indicators beyond income, the region scores only 57.3 as the Social Progress Index. 98.5 percent of its 772 municipalities are below the national average of 67.7 for the Index (Imazon, 2014).

Economic and social development indicators are thus low, in spite of massive development efforts based on mining, exploitation of forests and conversion of vast areas to pasture and more recently cultivated land. From the 1970´s to 2017, 768,935 of the original 4.1 million km^2 of natural forest have been lost. While some have argued that this is proof of the development model of forest conversion not working, others have claimed that the expansion of agriculture has not gone far enough (on this debate see for example Homma 2005).

Deforestation rates have and continue to vary strongly over time, but have generally come down significantly from the 2-3 million ha/year registered in the late 1970s and again in the early 2000s, to 0.5-0.8 million ha/year since 2009. In addition to other environmental impacts, deforestation has released very large amounts of CO_2 previously stored in forest biomass. The control of deforestation has drastically reduced these emissions, but forest loss continues to be the single biggest contributor to emissions of greenhouse gases by Brazil. The future of the forest sector is therefore critical for meeting Brazil´s obligations under the Paris Climate Agreement.

While forests have been lost at a rapid pace, there have also been considerable efforts to protect forests from conversion through conservation or sustainable use. Fully 15 percent of the Brazilian Amazon, some 60 million ha, are protected under a network of 117 conservation units (World Bank, 2018). Can sustainable use and a ´bio-economy´ improve the lives of presently poor people in the Amazon? What would a reduction of deforestation in line with the Nationally Determined Contribution of Brazil to the Climate Agreement mean for the people in the region?

Notwithstanding the intense controversy about which model is ´right´ raging for decades, little research has gone into quantifying impacts of alternative courses of action on economic growth, employment and income.

2. Land-use, employment, incomes and economic development - A Social Accounting Matrix for the Brazilian Amazon

Information about the capacity of different forms of land-use in the Amazon to create employment, generate income and contribute to economic development is scarce. This is particularly true when it comes to comparing different types of land-use in a disaggregated manner, for example comparing cattle rearing with crop production, timber and non-timber forest products.

In order to fill this information gap, a highly disaggregated Social Accounting Matrix (SAM) was built for the base year 2005 based on the most recent input/output table published at the time (for a more detailed presentation see Ferreira Filho & Fachinello, 2015).

A SAM organizes disperse data from the national accounts, but also census data as well as enterprise and household surveys, into a single, coherent framework. It captures the circular flow of the generation of value added, its distribution and use for consumption, investments and savings. Incomes and expenditures (rows and columns) by definition must be equal. Someone´s expenditure is someone else´s income. This turns a SAM into an ´x-ray´ of the economy, revealing interrelationships between sectors and regions. A limitation of this type of matrices is that it is a static framework with essentially fixed relative prices. This constraint should be recognized but not overrated. Comparisons of input/output tables over time have shown that the underlying structure of an economy changes rather slowly.

What makes the SAM constructed for the Brazilian Amazon unique, is the disaggregation of the category ´forest harvesting and silviculture´ in the original Input/Output table for Brazil into the most important sub-products. The SAM reflects separately: timber products (roundwood and firewood), charcoal, natural rubber, Brazil nut (açaí) and other forest products. It also captures silviculture and fishing, broken down into extractive marine fishing, sweet water fishing and aquaculture in salt and sweet water. The activities are mapped to 10 categories of workers and wage and income flows as well as expenditure to and from 10 categories of families. The results provide a number of new and in some cases surprising insights.

The contribution to GDP (national income) of the forestry sector is much higher in the Amazon (5.3 percent) than for the country as a whole (1.3 percent). Similarly, the Amazon forests play a bigger role as providers of employment and source of income (see Table 1).

Taking together the employment in extraction and in wood industries, forests and their products directly employ a total of 525.358 workers[1] in the Amazon. This is much more than previously thought based on administrative records but also when compared to the findings of dedicated surveys. Hummel *et al.* (2010), for example, report only 344,000 jobs based on forests for 2004, even though they include indirect employment both upstream (suppliers) and downstream (processing and marketing). The causes of these discrepancies merit further exploration to improve reliability and consistency of data concerning forestry in the Amazon. A surprising finding are the approximately 116,000 workers in river fishing.

With 8.7 percent of total employment, forest-related activities play a much bigger role in the Amazon than nationally, where they only account for 1.7 percent. To fully appreciate these numbers, it needs to be borne in mind that even in the Amazon, less than 30 percent of the population lives in rural areas. In spite of the disproportional weight of forests in the region, however, agriculture (26 percent) and animal husbandry (11.7 percent) are more important employers.

A characteristic of all four sectors - crop production, animal husbandry, fishing and forestry -, is that incomes are very low. Most workers are occupied in the lowest wage classes. In the case of forestry fully two thirds. In this regard, forestry work in the Amazon does not compare favorably with work in the sector elsewhere in the country, where forestry employs more workers in higher categories and affords higher wages than agriculture. In the Amazon, forests (and fisheries) are a significant source of employment for workers with low skill levels.

A SAM also allows to assess the relative contribution different economic activities can make to economic growth and job creation by calculating multipliers based on the interrelations between the sectors. This is very relevant when assessing investment trends and even more so, when considering public development policy. As can be seen in Table 2, forestry activities generally have employment multipliers that are as high or higher than those for agriculture.

Table 1. Employment and Income in the Brazilian Amazon in 2005

Activity	Gross Production Value US$ million		Income (US$ million)		Employment (number of workers)		Share (%) in total employment in the region
	Amazonia	Rest of Brazil	Amazonia	Rest of Brazil	Amazonia		Amazonia
Agriculture/livestock and fishing							
1) Agriculture	8.271.11	22 495.30	4.979.57	10 763 524	2 330 530		26.03
2) Timber Extraction	537.90	210.26	445.88	59 473	122 659		1.37
3) Charcoal from Extraction	79.70	191.11	63.49	17 750	5 861		0.07
4) Rubber extraction	3.20	0.00	2.66	5	5 367		0.06
5) Brazil Nut Extraction	17.86	0.00	12.20	0	9 600		0.11
6) Açai Berry Extraction	31.60	0.00	21.79	0	9 988		0.11
7) Extraction of Other Products	47.70	57.03	30.57	29 432	15 050		0.17
8) Timber Forestry	73.44	885.76	31.10	215 013	7 434		0.08
9) Charcoal from Forestry	13.88	91.40	4.27	13 705	631		0.01
10) Other Forestry Activities	0.19	42.08	0.13	2 938	9		0.00
11) Livestock	4 998.94	11 481.25	2 515.26	4 832 887	1 053 679		11.77
12) Maritime Extractive Fishing	157.81	428.92	148.18	239 937	82 448		0.92
13) Continental Extractive Fishing	198.18	91.18	186.08	50.944	103 586		1.16
14) Maritime Aquaculture	0.67	88.06	0.62	25 704	181		0.00
15) Continental Aquaculture	45.17	162.22	42.40	47 269	12 355		0.14
Industry							
16) Mineral Extraction	5 058.59	17 155.20	2 344.04	240 291	35 413		0.40
17) Agroindustry	6 045.45	16 693.83	1 263.02	1 646 951	126 685		1.41
18) Brazil Nut Processing	53.75	1.10	28.45	0	3 556		0.04
19) Açai Berry Processing	63.85	0.21	23.46	0	7 491		0.08
20) Slaughter of animals	1 758.06	5 820.88	429.97	384 204	28 111		0.31
21) Agricultural base manufactured products	445.61	14 525.53	156.17	3 515 644	34 509		0.39
22) Timber Industry	6 818.75	5 487.29	2 760.76	290 622	402 699		4.50
23) Metal Products	3 621.66	20 586.85	1 243.66	922 086	42 341		0.47
24) Manufactured products	5 087.48	51 385.11	1 796.14	2 724 544	116 055		1.30
25) Machines and Equipment	12 616.63	28 890.43	2 967.51	1 311 588	110 634		1.24
Services							
26) Public-utility industrial services	4 723.94	28 857.28	2 762.29	340 081	32 351		0.36
27) Construction industry	6 761.05	34 101.36	3 830.09	5 281 225	591 655		6.61
28) Trade	9 649.76	78 711.32	6 931.03	13 607 396	1 192 479		13.32
29) Transportation	5 167.57	36 923.69	2 811.90	3 526 023	265 017		2.96
30) Services	37 072.19	367 215.65	25 390.03	32 933 192	2 206 167		24.64
Grand Total (the 30 sectors)	119 421.68	742 578.09	63 222.72	83 022 426	8 954 542		100.00
Total vegetal extraction (4,5,6,7,18 and 19)	217.96	56.14	119.13	29 437	51 052		0.57
Total timber extraction (2,3 and 22)	7 436.36	5 888.66	3 270.14	367 844	531 219		5.93
Total forest (2-10, 18, 19 and 22)	7 741.83	6 964.05	3 424.76	628 937	590 346		6.59
Total fishing (12,13,14 and 15)	401.82	770.38	377.29	363 854	198 570		2.22

Source: Ferreira Filho & Fachinello (2016)

They are particularly high for non-wood forest products like rubber and Brazil nut as well as for fishing. These activities are very labor intensive and increased demand for their products generates large numbers of jobs. The downside is however, that incomes from non-wood products (though not from fishing) are very low. This reflects very low levels of productivity. Stimulating non-forest products in their current form would thus make a very limited contribution to poverty reduction. Another major limitation to the contribution that non-wood forest products can make to employment, income and economic growth is scale. Only three of the products (natural rubber, acai, Brazil nut) have volumes large enough to capture them in a macro-economic view of the

Table 2. Multipliers and Weighted Linkage Indices of the forest SAM for the Brazilian Amazonia in 2005

Activity	Multipliers			Weighted Linkage Indices	
	Product	Income	Employment	Backward (BIL)	Forward (FIL)
Agriculture	2.04	1.10	151	1.11	1.36
Timber Extraction	2.00	1.31	122	1.13	0.09
Charcoal Extraction	2.00	1.27	58	1.11	0.01
Rubber extraction	2.02	1.33	718	1.14	0.00
Brazil Nuts Extraction	1.99	1.16	249	1.02	0.00
Açai Berry Extraction	2.01	1.16	157	1.03	0.01
Extraction of Other Products	2.00	1.11	157	1.01	0.01
Timber Forestry	1.81	0.79	63	0.84	0.01
Charcoal Forestry	1.96	0.72	49	0.74	0.00
Other Forestry Products	1.88	1.08	44	0.00	0.00
Livestock	2.33	1.09	136	1.13	0.95
Maritime Extractive Fishing	2.13	1.49	250	1.13	0.04
Continental Extractive Fishing	2.13	1.49	250	1.13	0.05
Maritime Aquaculture	2.13	1.49	147	0.00	0.00
Continental Aquaculture	2.13	1.49	148	1.13	0.01
Mineral Extraction	2.25	1.06	35	1.35	0.63
Agroindustry	2.62	0.96	82	1.20	1.69
Brazil Nut Processing	2.38	1.22	131	1.08	0.00
Açai Berry Processing	2.51	1.15	141	1.03	0.02
Slaughter of Animals	2.76	1.03	95	1.14	0.54
Agricultural Based Manufact. Products	2.13	0.84	67	0.90	0.12
Timber industry	2.39	1.05	69	1.19	0.73
Metal Products	2.30	0.92	33	1.13	0.58
Manufactured products	2.10	0.85	38	1.06	1.25
Machines and Equipment	2.21	0.70	29	1.26	1.73
Public-utility industrial services	2.26	1.17	31	1.31	1.23
Construction industry	2.06	1.05	65	1.12	0.64
Trade	2.10	1.26	83	1.40	2.35
Transportation	2.04	1.03	50	1.20	1.25
Services	2.12	1.24	57	1.82	7.16

Source: Ferreira Filho & Fachinello, 2016.

region. Evan those remain niche products and unrealistically large increases in production would be needed to make a substantial contribution to the development of the region.

This is true, even though forest-based activities, with the exception of the wood industry and of fishing, have a substantial potential to boost economic growth in the Amazon region. Timber and fishing have multiplier effects as high as agriculture. It is thus not true, as is sometimes claimed, that expanding crops or cattle rearing is better for growth than forest-based activities.

In particular, timber extraction, rubber and fishing have high backward linkages, i.e. they require substantial local inputs. Strengthening these value chains can thus make a significant contribution to local development.

The latter is one of the big challenges. The separation of the Amazon economy from that of the rest of Brazil and the ´rest of the world´ exposes the economic dependence status that the Amazon has vis-à-vis both: all multipliers are significantly lower in the region than for Brazil as a whole. This is a consequence of high dependency on inputs from outside the region on the one hand and the short value chains in the Amazon with little local value addition on the other.

As the discussion has shown, a macro-perspective with a high resolution in terms of sectors, types of workers and households shines a rather different light on actual and potential contributions to economic growth, employment and income generation – in particular for non-forest products – than is often advocated. The analysis also demonstrates how important it is to consider not only economic growth and the number of jobs, but also the income levels associated with them.

3. Amazon forests and climate change

Over the last decades, the discussion about land-use in the Amazon has been complicated further. The recognition of the threats from uncontrollable climate change and of the vital role of forests generally and of the Amazon forest in particular, has put forests into focus as stores of and potential sinks for CO_2. Deforestation in the Brazilian Amazon in 2005 was responsible for 60 percent of all emissions in Brazil and accounted for 2 percent of all global emissions (Imori *et al.*, 2011).

Since the introduction of the Program to Combat Deforestation in the Amazon, emissions from deforestation have fallen dramatically in Brazil from 2,000 million tons CO_2 in 2004 to around 500 m tons in 2014. The latter level is similar to emissions from the energy and agricultural sectors (Rezende *et al*., 2018). Avoided deforestation has been the only substantial reduction of emissions in Brazil. Deforestation control is therefore a critical policy target in the Brazilian Nationally Determined Contribution (NDC) to global reductions of greenhouse gases.

When adopting such policies, it is important to assess their potential economic and social impacts. This is particularly relevant if policies could affect regions and groups disproportionately. The preamble of the Paris Climate Agreement therefore calls for a just transition for workers when reducing emissions[2] (UN, 2015).

An extensive review of the impact of environmental, in particular climate protection policies on employment shows that they lead to net gains in most cases, i.e. more jobs are created than are lost. The net gains are typically in the order of 0.5-2 percent of the economically active population. There are almost invariably losers from such policies as well, however, which need to be attended to for social as well as political reasons (Poschen, 2015).

In order to assist countries and stakeholders in achieving just transitions, the International Labor Organization adopted Guidelines (ILO, 2015). One of the key recommendations in the Guidelines is the ex-ante assessment of employment and income effects of climate policies. The ILO also published a manual on data collection and processing (ILO, 2017).

Ferreira Filho *et al.* (2017) carried out an ex-ante assessment of deforestation reduction scenarios in Brazil and the associated social costs caused by restricting the expansion of agriculture and livestock, in particular in the agricultural frontier regions in the Amazon. As has been pointed out above, the population in these regions has some of the worst welfare indicators in Brazil.

The study used a general equilibrium model for Brazil, the TERM-BR model, designed especially for the analysis of land-use change (LUC), based on previous work by Ferreira Filho & Horridge (2014). The TERM-BR is a recursive, bottom-up, dynamic computable general equilibrium (CGE) model. It includes a detailed regional representation of Brazil, with 27 regions (26 states plus the Federal District), 110 products and 110 productive activities, 10 types of families (classified by family income bracket) and 10 types of workers (classified by salary range). Unlike SAMs, CGE models capture changes in relative prices and are suitable for simulations over longer time periods.

TERM-BR brings new detailed estimates of deforestation and land use in three important biomes in Brazil: Amazonia, Cerrado (Savannah) and Mata Atlantica (Coastal Rainforest). This information is available by state and by type of agricultural aptitude, by region and biome, and by type of land ownership (public or private). The data were obtained from satellite imagery and reflect land use changes observed between 1994 and 2002 (Brasil, 2010). They allow a detailed representation of the deforestation process by region and biome.

This information was processed to distinguish three major types of land use: Crops (CROP), Pastures (PASTURE) and Forestry (planted forests, FORESTRY), and a residual type identified in the model as UNUSED, which represents natural forests. The resulting transition matrices are detailed by state and, within each state, by six distinct biomes: Amazonia, Cerrado, Caatinga (dry forest), Atlantic Forest, Pampa (natural grasslands) and Pantanal (wetlands).

In order to assess the impacts of policies, the study compares policy scenarios with an extrapolation of existing trends, a Business-As-Usual scenario for the period 2016-2030. The three deforestation scenarios simulated were:

- Scenario 1 (DZabs): Absolute zero deforestation. This is the most extreme scenario, in which deforestation is completely halted between 2016 and 2030, both on public and private land.

- Scenario 2 (DZ2): The rate of deforestation on all public land and on private land in the Mata Atlantica biome follows the current trend until 2020, after which it is reduced until it stops in 2030. Deforestation on private land in the Amazonia and Cerrado biomes follows the current trend, but only in non-protected natural vegetation (legal deforestation), and only on land highly suitable for agriculture (agricultural aptitude above the 0.80 percentile).

- Scenario 3 (DZ3): The rate of deforestation on public land, and on private land in the Mata Atlantica biome follows the current trend until 2020, when it starts to slow until it stops in 2030. Deforestation on private land in the Amazonia and Cerrado biomes follows the current trend, irrespective of its agricultural suitability.

All scenarios assume that deforestation will occur only in stocks of unprotected native vegetation in accordance with the requirements of the Brazilian Forest Code (environmental assets), i.e., only native vegetation outside Permanent Protection Areas (APP) and Legal Reserves (RL) is converted[3] . They do not assume restauration of PPPs and RLs, however, where they had not been established.

In all scenarios, areas of crops, forestry, and deforestation are projected exogenously in the baseline. The pasture area is the variable that adjusts to stay within the available total stock of land. Pasture was chosen as the adjustment variable because crop production generally has higher rates of return. The result would be a reduction of 31.1M ha in the area of pasture in the baseline, from 2016 to 2030.

The first scenario is only for reference, an upper bound for the economic impacts of deforestation control policies. While this most ambitious scenario matches the target proposed by the New York Declaration on Forests issued by the United Nations Climate Summit 2014 (United Nations, 2014), Brazil has not endorsed it (Ferreira Filho *et al.*, 2015).

The DZabs scenario, which simulates the total interruption of deforestation from 2016, would avoid deforestation of an area of natural forests of 13.7 M ha compared to the BAU accumulated in 2030. The total gain in forest areas (and corresponding loss of pasture areas) in scenario DZ2 would be only 5.6 M ha, reduced to 0.95 M ha in the DZ3 scenario.

What would be the economic impact? Model results show that GDP loss accumulated in 2030 is relatively small. The highest observed loss would be a fall of 0.62% of GDP accumulated until 2030 in the DZabs scenario. This is the social cost of avoided deforestation (or the shadow value of deforestation), taking into account all associated economic losses in the economy.

In monetary terms, GDP losses accumulated up to 2030 and expressed in 2016 values are estimated at US$ 12.9 billion (US$ 862 million per year) for the DZabs scenario, US$ 4.7 billion (US$ 312 million per year) for the DZ2 scenario, and US$ 639 million (US$ 43 million per year) for the DZ3 scenario. Only as a reference for the orders of magnitude involved, the total volume of rural credit made available in Brazil in 2016 was US$36.7 billion (Banco Central do Brasil, 2017).

While the social losses are rather small as a share of national GDP, the income losses are much higher in some states. As can be seen in table 3, states on the agricultural frontier would typically lose more than the average in all scenarios. The states of Pará, Rondonia, Mato Grosso and Acre would be the most affected with losses from 2.05-4.53 percent under DZabs.

Another relevant question is how the losses would impact different social groups. The lowest wage earners are concentrated in lower income families, and vice versa. A greater fall in the wages of the less skilled workers thus tends to affect the incomes of the poorest families more negatively. Because food accounts for a high share of their expenditure, poor families could also be impacted by rising prices for agricultural products caused by lower production.

Table 3. Percentage change in regional GDP. Cumulative in 2030.

Real GDP	DZabs	DZ2	DZ3
1 Rondonia	-3.07	-1.53	-0.59
2 Acre	-4.53	-2.88	-0.54
3 Amazonas	-0.55	-0.12	-0.06
4 Roraima	-1.47	-0.32	-0.14
5 Para	-2.05	-1.35	-0.23
6 Amapa	-0.64	-0.19	-0.05
7 Matopiba	-1.04	-0.45	-0.04
8 PernAlag	-0.40	-0.15	-0.02
9 RestNE	-0.44	-0.15	-0.02
10 MinasG	-0.48	-0.13	-0.03
11 SaoPaulo	-0.38	-0.13	-0.01
12 RestSE	-0.17	-0.06	0.00
13 Sul	-0.65	-0.21	-0.02
14 MtGrSul	-1.11	-0.30	-0.04
15 MtGrosso	-3.17	-0.91	-0.14
16 GoiasDF	-0.99	-0.29	-0.04

Source: Model results reported in Ferreira Filho (2017)

Table 4 shows that both concerns are relevant. There are higher real wages losses in the DZabs scenario for the less qualified workers (OCC1 to OCC4), which would fall by as much as 6.30% in Pará and 6.50% in Mato Grosso. Poor families in agricultural frontier states would be hit by income losses and expenditure increases, particularly in the state of Mato Grosso, where the accumulated loss in 2030 would reach 6.03 percent.

Before discussing the policy implications of these findings, two observations are important. First, the modest magnitude of the observed social loss suggests that relatively small increases in the rates of technical progress compared to BAU could compensate for these losses.

Second, environmental gains from less deforestation have not been analyzed in the study. As noted earlier, these gains are not captured by the circular flow of income in the economy. They are probably very high when computed in all their dimensions as shown by results of the TEEB Initiative (see The Economics of

Table 4. Percentage change in real regional wages, Pará and Mato Grosso States. Cumulative in 2030.

Workers by wage decile	DZabs		DZ2		DZ3	
	Pará	Mato Grosso	Pará	Mato Grosso	Pará	Mato Grosso
1 OCC1	-3.14	-5.18	-1.54	-1.85	-0.23	-0.31
2 OCC2	-6.30	-5.80	-3.79	-1.84	-0.58	-0.33
3 OCC3	-3.13	-5.68	-1.74	-1.67	-0.28	-0.32
4 OCC4	-2.54	-6.50	-1.42	-1.72	-0.22	-0.32
5 OCC5	-3.72	-4.73	-2.17	-1.36	-0.34	-0.26
6 OCC6	-3.31	-4.88	-1.89	-1.47	-0.30	-0.28
7 OCC7	-2.58	-2.95	-1.45	-0.94	-0.23	-0.16
8 OCC8	-1.82	-1.72	-1.01	-0.49	-0.16	-0.09
9 OCC9	-0.27	-1.50	-0.07	-0.45	-0.01	-0.08
10 OCC10	-1.95	-1.50	-1.10	-0.45	-0.17	-0.09

Source: Model results reported in Ferreira Filho (2017)

Ecosystems and Biodiversity at [http://www.teebweb.org/]. Indeed, this is a frontier area in applied economic research, and one with high priority in future methodological development efforts.

4. Conclusions and policy implications

Economic modelling with a macro perspective but also a high resolution in terms economic sectors, types of workers and households sheds a different light on the merits and implications of development strategies in the Amazon region.

The historical development model for the Amazon based on the exploitation of mineral resources and hydropower as well as on the conversion of large areas of natural forest into pasture and more recently agricultural land, has not worked. It has cemented rather than broken the colonial nature of the regional economy with very limited local value addition and high dependence on imported inputs. The economic multipliers of cattle rearing and crop production are not higher than those for sustainable use of forests. Conversion is thus not a more effective driver of economic growth.

The SAM suggests that forests employ many more people directly than previously thought. Similarly, fishing in river systems in the Amazon is much more important as a source of employment than hitherto realized.

All activities based on land-use (agriculture, forestry and fishing) have similar job creation potential per unit of economic output. With current technology and value chains however, they also have high proportions of unskilled and low paid work. This is particularly true for non-wood forest products, where productivity is very low.

Reducing deforestation in the Amazon is critical in order to reach Brazil´s targets for emissions reduction. This is also likely to preserve a vast and unexplored potential to build a sustainable regional economy on the biological assets and traditional knowledge of indigenous peoples in the region. The cost of preserving forests in terms of lost economic growth is rather small for the country as a whole. It does, however, fall disproportionately on agricultural frontier states. The losses in terms of lost employment opportunities, lower wages and higher cost of food products impact poor workers and households significantly and much more than those which are better off. The findings of the studies and international experience support the call by Pacheco *et al.* (2016) to go ´beyond zero deforestation in the Brazilian Amazon'.

Increases in productivity are essential, both in land-use and for labor. For labor, it is indispensable to increase

the often very low remuneration and thus family incomes. Without that, poverty reduction will remain an elusive objective and environmentally sustainable forms of land use are not attractive enough for local populations in the medium term and likely to be abandoned.

For land use, it is crucial to compensate for the reduced pasture areas and to continue to increase crop output without having to convert additional forest. Brazil has an impressive track of improving agricultural productivity. As pointed out by Pacheco *et al.* (2016), the challenge will be to make better use of degraded land, take advantage of natural resources and ecosystem services and to develop technology and values chains in ways which are accessible to smallholders.

It will also be critical to enhance local value addition. The experience with manufacturing based on natural rubber in Acre is a case in point. The polarized debate of the past between a purely market-driven and a conservation logic has been unhelpful. In a region as vast and diverse as the Brazilian Amazon, many customized and locally adapted solutions are needed. There is also evidence that they are possible (see for example Pokorny, 2013 or UNDP, 2016). Local economic development will require investment in local governance capacity and have to adapt instruments such as payments for environmental services and mechanisms such as public support for local value addition to the context of smallholders and dispersed communities.

Sustainable use of forests – wood and non-wood products – will continue to be critical for the region, but needs to pay more attention to economic viability, both for the value chain as a whole and for workers. Non-wood forest products are likely to make a contribution to local livelihoods, but will only in exceptional cases and in some locations have the potential to provide adequate levels of income. Wood products remain central but are struggling. As Hummel *et al.* (2010) have shown through a time series of surveys, the massive waste of timber has been reducing and helped economic viability, but local value addition remains low. Timber from natural forest has been losing ground against wood grown in plantations and other materials.

Transfers like the Bolsa Familia have played an important role to reduce poverty in the region and to break the generational cycle of poor health and education compromising the potential of the next generation. The Bolsa Familia and programs like the Bolsa Floresta could be developed further to strengthen local skills, capacity and value addition. As part of just transition strategies for economic diversification in agricultural frontier states, they could be coupled with investments to explore and use the bio-economy potential of the region. Experience in the OECD region shows that this would require substantial investment not only in production facilities but also in skills (OECD, 2018).

In the short run, they will also be vital to compensate low skilled and poorly paid workers for the losses they incur from reduced deforestation. Failing to do so, could lead to a cycle of destruction, for example, if former farm and cattle workers engage in informal small-scale mining using mercury, thereby further contaminating rivers and fish which would put the main protein source at risk and threaten another major source of employment and income for workers with low skills.

Finally, ex-ante analysis of economic, social and environmental impacts such as those described in this article should be periodically and routinely conducted. As has been shown, they provide critical information for policy makers as well as local stakeholders. This provides a better factual basis for policy making and local participation. Carrying out, validating and discussing such assessments can usefully be linked to improved local governance and monitoring of land-use and multiple dimensions of development.

NOTES

[1] Employment is expressed as full-time equivalents. Since a lot of the work is part-time and seasonal, the total number of persons involved is much higher still.

[2] The preamble calls for: *´Taking into account* the imperatives of a just transition of the workforce and the creation of decent work and quality jobs in accordance with nationally defined development priorities.

[3] Maintenance of Permanent Protection Areas (PPP) and Legal Reserves (RL) are mandatory for native vegetation in farms under the Brazilian Forest Code.

REFERENCES

Banco Central do Brasil. (2017). *Matriz de dados do crédito rural. Evolução dos recursos financeiros.* Retrieved [12-09-2017] from [https://www.bcb.gov.br/ptbr/#!/c/MICRRURAL/].

Brasil. (2010). *Segunda Comunicação Nacional do Brasil à Convenção-Quadro das Nações Unidas sobre Mudança Global do Clima.* Brasília: MCT. Retrieved [13-02-2002] from [http://www.mct.gov.br/index.php/content/view/326751.html].

Ferreira Filho, J. B. S & Horridge, M. (2014). Ethanol expansion and indirect land use change in Brazil. *Land Use Policy, 36,* 595– 604.

Ferreira Filho, J. B. S. & Fachinello, A. L. (2006). *A geração de emprego e renda na Amazônia Brasileira.* Brasília: International Labor Organization.

Ferreira Filho, J. B. S. & Fachinello, A. L. (2015) Employment and income generation in the Brazilian Amazon forest: a SAM based multiplier approach. *International Forestry Review, 17*(1), 85-96.

Ferreira Filho, J. B. S. (2018). Economic and social impacts of deforestation reduction in Brazil. *GTAP, Conference paper.* Cartagena, Colombia.

Ferreira Filho, J. B. S., Ribera, L. & Horridge, M. (2015). Deforestation control and agricultural supply in Brazil. *American Journal of Agricultural Economics, 97,* 589-601.

Homma, A. K. O. (2005). Amazonia – como aproveitar os beneficios da destruicao. *Estudos Avançados, 19*(54), 115- 135.

Hummel, A., Alves, M. A. da S., Serrão Pereira, D., Veríssimo, A. & Santos, D. (2010). *A atividade madeireira na Amazônia brasileira: produção, receita e mercados.* Belém: Serviço Florestal Brasileiro, Instituto do Homem e Meio Ambiente da Amazônia.

IBGE. (2017). *Sintese de indicadores sociais 2016.* Retrieved from [https://agenciadenoticias.ibge.gov.br/agencia-sala-de-imprensa/2013-agencia-de-noticias/releases/18824-sintese-dos-indicadores-sociais-um-em-cada-quatro-jovens-do-pais-nao-estava-ocupado-nem-estudava-em-2016].

ILO. (2012). *Working towards sustainable development: opportunities for decent work and social inclusion in a green economy / International Labour Office.* Geneva: ILO.

ILO. (2015). *Guidelines for a just transition towards environmentally sustainable economies and societies for all.* Geneva: ILO.

ILO. (2017). *GAIN Training Guidebook - How to measure and model social and employment outcomes of climate and sustainable development policies. Green Jobs Assessment Institutions Network, 2017*. Geneva: ILO.

Imazon. (2014). *Índice de Progresso Social na Amazônia brasileira.* Belém: Instituto do Homem e Meio Ambiente da Amazônia.

Imori, D., Guilhoto J. J. M., Scretas David, L., Gutierre, L.M. & Waisman, C. (2011). *The development of the Brazilian amazon region and greenhouse gases emission: a dilemma to be faced!*. University of Sao Paulo. Retrieved from [https://mpra.ub.uni-muenchen.de/31132/1/MPRA_paper_31132.pdf].

Pacheco, P., Pikett M. G., Poccard- Chapuis, R., Garcia-Drigo, I., Chaar El Husny, J., Gomes, M. & Tourrand, J. M. (2016). Beyondzero deforestation in the Brazilian Amazon - Progress and remaining challenges to sustainable cattle intensification. *CIFOR Info Brief, 167*.

Pokorny, B. (2013). *Smallholders, forest management and rural development in the Amazon.* London: Routledge.

Poschen, P. (2015). *Decent Work, Green Jobs and the Sustainable Economy – Solutions for climate change and a sustainable economy.* Sheffield: Greenleaf Publishers.

Rezende de Azevedo, T. *et al.* (2018). *SEEG initiative estimates of Brazilian greenhouse gas emissions from 1970 to 2015*. Retrieved [8-08-2018] from [https://www.nature.com/articles/sdata201845.epdf].

UN. (2015). *United Nations - Paris Agreement*. Retrieved [31-07-2015] from [http://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf].

UNDP. (2016). *The Amazon and the 2030 Agenda. Policy paper.* New York: United Nations Development Program.

World Bank. (2018). Preservar a Amazônia gera empregos e paz para a América Latina. Retrieved [9-08-2018] from [http://www.worldbank.org/pt/news/feature/2018/02/22/brasil-amazonia-preservacion-programa-arpa].