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Biomass fires: preliminary estimation of ecosystems global economic losses

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Highlights

- Globally, biomass fires are burning yearly (in average) between 3 and 4.5 million km^2 depending on years and sensor used. Africa is by far the main region affected.
- Biomass fires affect both local and global environment. With impacts to local biodiversity, soil, as well as produce large amount of Green House Gases affecting the global climate.
- Methodologies for evaluating the value of ecosystems (and related services) are still in their preliminary stage and there are large level of uncertainties and margins of errors.
- Despite these gaps in knowledge, even using a conservative approach based on minimal values lead to colossal economic losses bringing a new light on the economics of wild fires impacts. Globally the economic direct losses are between several dozen to hundreds of billions each year. To these values, the cost of the recovery period should be added, the global economic losses are likely to exceeds hundreds billion US$ per year.
- We cannot leave such level of uncertainties associated with such potential high economic losses. It is therefore a priority to improve the methodologies so that margins of errors are largely decreased.

Note: This is a work in progress much more work is needed for improving the methodology. Results presented here are only for discussion purpose, to flag what needs to be improved. However, the evaluation is voluntary conservative; figures presented here are likely to be much lower than the real losses.

Introduction

Globally, biomass fires are burning between 3 – 4.5 million km^2 per year, this is an area equivalent to India plus Pakistan or more than half of Australia. Fires are used for conversion to cropland, as a result of poor agricultural practices or due to dryer conditions than usual. Fires of natural origins are ignited by lightening and can be part of the ecosystems (e.g. in boreal forests), in other regions (e.g. Australia, African savannah,…) fires has been used by humans for thousands of years and is now part of these ecosystems, although not natural (it is still mostly ignited by humans) it can be considered as usual. Fires are also prevalent in temperate forests and in Mediterranean vegetation. Fires are also been used for clearing land, e.g. for converting forest to cropland, in this case fires can lead to large impacts on ecosystems. Due to the significant territorial extent yearly affected by fires, wild fires have become an important factor of global change. Wild fires (biomass burning) is a hazard including both systemic and cumulative effects on global change (Peduzzi, 2012). Fires are emitting Green House Gases (GHG) which have a systemic impact on climate, while they cause deforestation producing cumulative impacts, e.g. on biodiversity and soils (Turner et al, 1990).

For farmers fire offers multiple benefits, it is a cheap way to clear land, which otherwise would request heavy machinery. It kills pests (such as snakes, insects, scorpions,…), it induces a regrowth of young green grass which is appreciated by cattle. It helps to quickly convert forest into cropland, rapidly extending the area for agriculture productivity.

However, impacts from biomass fires are numerous and severe. They include loss of soil cohesion from heat, which then accelerate soil erosion (from wind or rain), it destroys complex ecosystems and thus has a significant impact on biodiversity, it emits GHG, biomass fires are responsible for 17.4% of GHG global emissions (Solomon *et al.*, 2007). Biomass fires impacts highly depends on type of vegetation and location. In rainforest ecosystems it produces large destruction and is a threat to this ecosystem. The natural cycles of fires being very long, hundreds to thousand years (Cochrane et al., 1999) the current prevalence of fires disruptions has reduce it to 5- 10 years, thus not allowing the ecosystems to regenerate.

Despite the large areas impacted, biomass fires are not ranking high on reported losses (as reported by EM-DAT). An average of 70 killed per year, 0.1% of reported mortality (0.01 – 1.24% of total) in the last decade

(2002-2011) and 2.4 billion average reported losses (between 3 and 6 billion US$), i.e. less than 1.9% of total reported economic losses (0.01 – 8.73%) between 2002 and 2011. However, these relatively low figures are the result of our poor understanding on the economic value of ecosystems losses. Most of the economic losses reported are about the value of properties or timber, but forests provide numerous services which should better be acknowledged. Ecosystems services provided by forest include : carbon storage, production of dioxygen (O_2), production of biomass (used for timber, fire wood, building,…), recreational value, intrinsic and support to biodiversity, protection of water sources, reduce soil erosion, production of pharmaceutical products. Forests also participate to local climate (colder temperature, darker albedo and rougher surface can lead to higher precipitations), shade of forests are protecting water sources, humidity content in the vegetation is a source of inertia for regulating dry periods. The canopy multiplies the surface of evaporation, evapo-transpiration processes participate to the re-formation of clouds allowing rainfall to enter further in-land in continental areas. Finally, forests have beauty value (landscape) and spiritual values.

Given the multitude services provided by ecosystems, assessing their economic value is difficult. Also some values are priceless, e.g. what is the value of the production of dioxygen that we are breathing? How much worth the biodiversity or soil protection? Despite the difficulties, placing a price on ecosystems would help to having them better considered. Failing to do so, ecosystems will continue to be replaced by other production surfaces (crops, golf courses, urban, housing) for which the price is known. When a value is unknown it tends to be assimilated to null. The Millennium Ecosystems Assessment (MEA, 2005) is a milestone and set the stage for global evaluation of ecosystems. It shows that harvested timber had a value of $ 400 billion in 2000, meaning ecosystems services have high economic value. However the methodologies are still in preliminary stages. While progress were made and studies performed in detail in various specific locations (see references in TEEB valuation Database online) there are very few studies and our understanding is still very limited.

This study aims at identifying current available information for quantifying the economic losses from burnt ecosystems. However, its main objective is to highlight gaps and identify where improvements are needed in order to achieve a more precise evaluation of these economic losses. We are providing here a trend on observed burnt areas by region and by ecosystems and a first conservative estimation of the global economic losses from burnt ecosystems.

This is a four step process which will be described further below, we first took the measured area burnt from two different satellite sensors, then overlay this information to a land cover map to gain understanding on what ecosystems was burnt, we used a synthesis of the methodology developed by UNEP/TEEB to have minimum, median and maximum value of each ecosystem. We multiplied these value by the ecosystems burnt and aggregated these figures by year, region and ecosystems. Our findings revealed that there is so far a very poor understanding of burnt areas and ecosystem economic value. This translated in large uncertainties and significant margin of error (we will not try to hide this, but rather to give a full appraisal of these uncertainties). However, even considering minimum ecosystems value (conservative approach), once multiplied by the large areas burnt, the average minimum value was found to be 23 billion US$ per year, i.e. about 10 times the reported losses by EM-DAT on biomass fires, or 17.5% or total reported (by EM-DAT) economic losses from all natural origins.

This is already an impressive findings, but should we use a less conservative approach and take the median value (as opposed to minimum values), the economic losses from biomass fires would reach a yearly average of 300 billion US$ per year. For comparison the highest economic losses ever reported is from the Fukushima earthquake/tsunami/nuclear power plant accident in 2011 which is reported to reach 210 billion US$ by EM-DAT and which account for 57.7% of the 363.7 billion economic losses of 2011, the highest reported losses ever reported. Meaning that under a median value scenario, an average biomass fires activity would account for more than 80% of the highest reported losses. Now, certainly we are not yet in a position to be firm on these numbers. The margins of errors are too large and the methodology relies on several shortcuts. What we are saying, is that the economic losses of ecosystems are colossal, yet largely unknown and even more broadly not even reported or considered. Given these high values and large areas affected by biomass fires, the methodology needs to be drastically improved so that better understanding and monitoring of these losses can be achieved.

Estimation of burnt areas

There are two products which were developed to measure global areas burnt. The first product (L3JRC) was developed by a consortium led by EU/JRC (Tansey *et al.*, 2004a and 2004b) for the year 2000, further refined (Tansey *et al.*, 2008) and applied over the years 2000-2006. It is based on SPOT Vegetation satellite sensors at 1 x 1 km resolution.

The second product (MODIS MCD45) was developed by the universities of Maryland and College of London (Roy *et al.* 2005) using Moderate Resolution Imaging Spectroradiometer (MODIS) satellite sensor, at a resolution of 500 m and fully applied on the period 2002 – 2011 (although the years 2000 and 2001 are partly covered). It was further modified at a 1 km resolution (using conservative aggregation) to allow comparison with the L3JRC dataset.

The L3JRC is providing larger burnt area values and higher fluctuation through years as compared with the MCD45 (Figure 1). The global sum is similar ranging between 3 - 3.5 millions km^2 for MCD45 and between 3.5 – 4.5 million km^2 for L3JRC. However, the similarities of the global level hide large discrepancies at regional level (Table 1). Most of the burnt area detected by MODIS MCD45 is in Africa (72.8%), while L3JRC algorithm detects a more complex distribution over the different continents, with Africa counting for 37.6%. The two products are providing very different assessments of burnt areas. Our comparison show that their agreement on common years (2002-2006) is, in average, limited to 22% (20 – 24 %). While the use of different sensors and algorithms can explain some differences, the large discrepancies is of high concerns for the reliability of fire scars detection and call for extensive verifications.

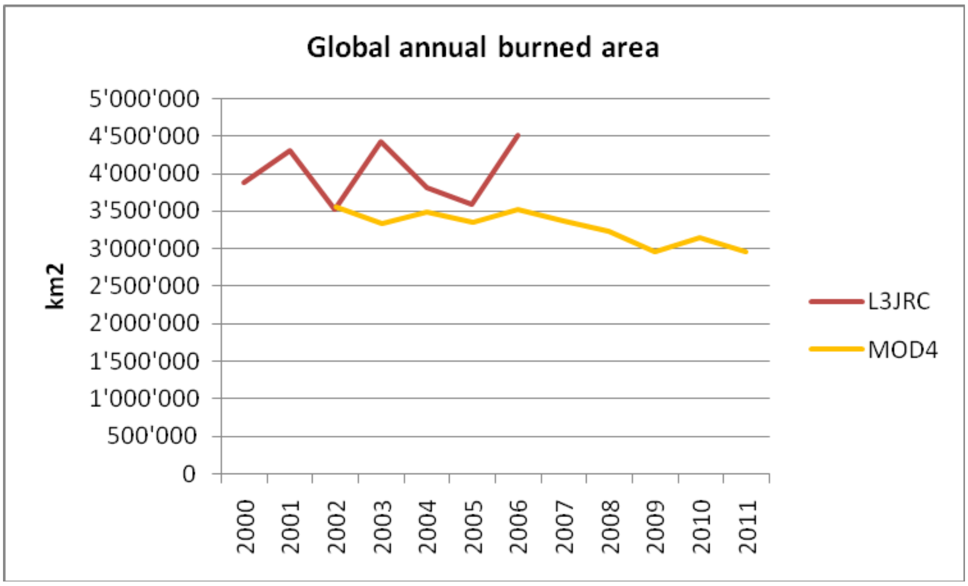


Figure 1 Comparison of global annual burned area

Regions	L3JRC	MCD45
Africa	37.6%	72.8%
Asia	13.0%	6.2%
Europe	19.2%	4.4%
LAC	10.6%	6.5%
North America	8.9%	1.0%
Oceania	10.6%	9.2%
Total burned area in thousand km^2 (as average)	3917	3276

Table 1 Average percentage of area burnt by region according to the different sensors

Biomass fires are used for agricultural practices at dedicated time, they also occur predominantly during dry seasons and dry spells. It is therefore possible to produce a calendar of fire-prone season (see Figure 2).

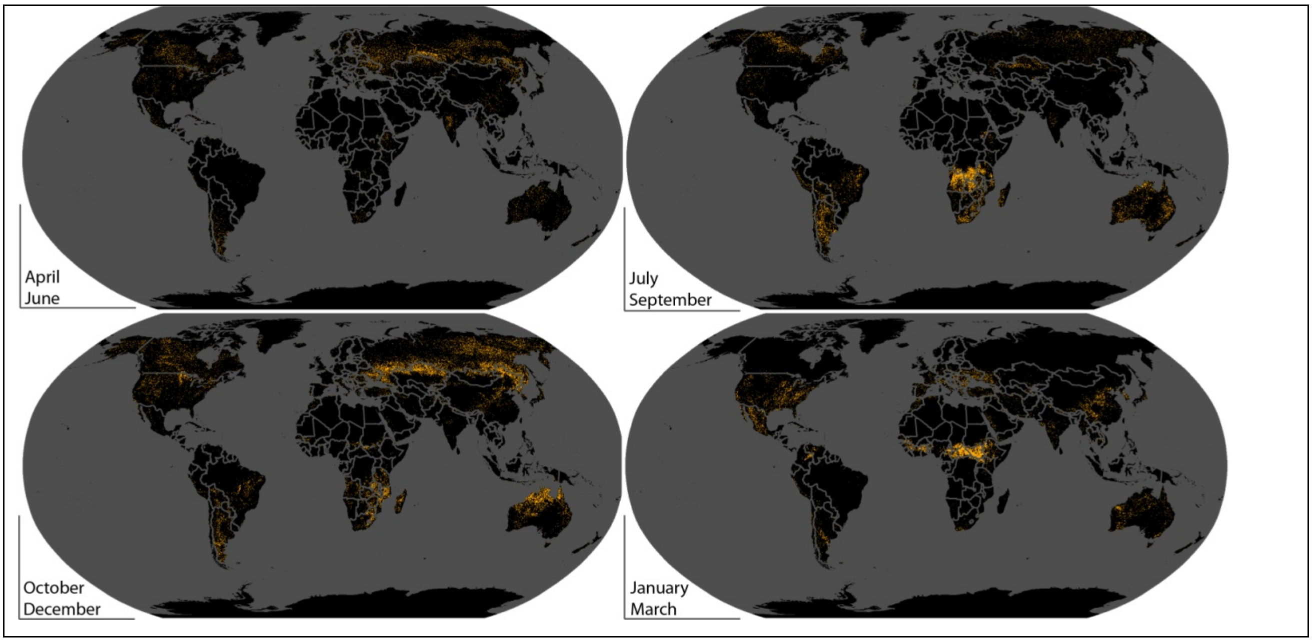


Figure 2 Fire seasons 2000 -2006 (source: L3JRC)

What is burning?

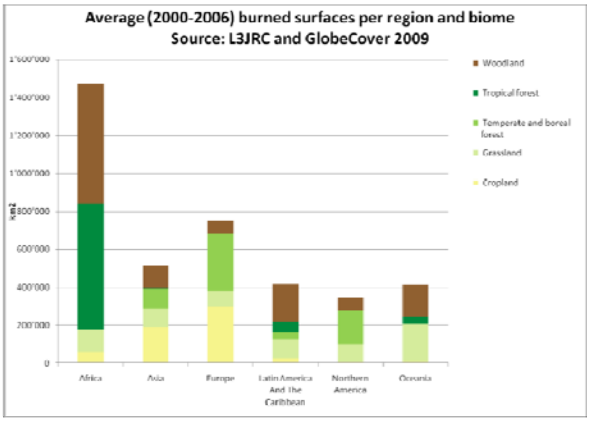
To gain understanding on what was burnt, the burnt areas were intersected with a global land cover map (GlobCover 2009, thereafter GC09). *GC09* land cover map (Figure 3) is produced by the European Space Agency (ESA, 2010) using semi-automated procedures by processing MEdium Resolution Imaging Spectrometer (MERIS) full Resolution data (300 m) collected from 1st January to 31st December 2009 (Arino *et al.*, 2010). It counted 22 categories compatible with the Land Cover Classification System (LCCS) from FAO (Di Gregorio and Jansen, 1998; Bicheron *et al.* 2008). Besides being the highest resolution global dataset of the category, it has the advantage to be compatible with its previous 2005 version allowing change detection analysis.

Figure 3 *GlobCover* 2009, (ESA) includes 22 categories of land cover at 300 m resolution.

The classification was simplified to match with the ecosystems economic values. We merged vegetation classes into 5 categories (also using spatial filters[1]): grassland, woodland, temperate & boreal forest, tropical forests and cropland. Economic evaluation was only performed for natural ecosystems, but cropland class was used to gain understanding on burning practices for agriculture.

We intersected the identified burnt areas were intersected with the reclassified version of GC09. Values were then aggregated by ecosystems and regions for statistical analysis purpose (Figure 4 and Table 2).

[1] We used 28° latitute for separating tropical forest from other forests (temperate and boreal)



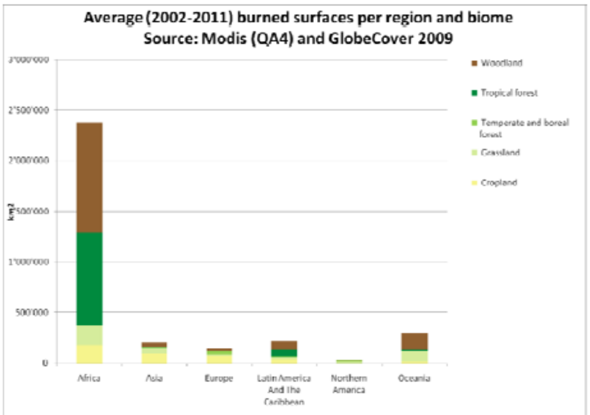


Figure 4 Average burned surfaces per region and biomes from L3JRC (left) and *MCD45* (right)

The association between *GC09* classes and broad five categories should be further refined, we acknowledge the caveats that we have simplified the analysis by only considering *GC09*. This is a deliberate choice, made due to short deadlines for delivering our results. Ideally we would like to overlay burnt areas with the corresponding year, but such global annual dataset does not exist yet (and will not in a near future). Despite the known caveats, it introduces errors, but this is not the main issue here. Using *GC09* is a way of being conservative, it underestimates the surfaces of burnt forests (e.g. forest burnt in 2006 would be classified as e.g. grassland or cropland in *GC09* and thus forest burnt in 2006 may be wrongly classified and values losses being reduced. However, given that this is a first approach, we preferred to use conservative approach, however this caveat has to be considered for refined analysis, e.g. by considering both GlobCover 2005 and 2009, or even yearly inter/extrapolation between these two dataset, it would not solve, but already reduce this issue.

Discrepancies between sensors are ecosystems specific. MCD45 detects (rightly or not) more area burnt in tropical forest and woodland as compared with L3JRC, while this one detects (rightly or not) ten times more burnt areas in temperate and boreal forest as compared with its competitor (Table 2).

Finally, GC09 is a semi-automated procedure and accuracy of the classification is also subject to error. Despite these known limitations, this is the only existing products for global level analysis and already provides a first evaluation.

Table 2 Percentage of area burnt by ecosystems (as average)

Ecosystems	L3JRC		MCD45	
	Percentage	*Total (in 10^3 km^2)*	*Percentage*	*Total (in 10^3 km^2)*
Cropland	15.0%	587	12.3%	404
Grassland	17.6%	688	12.1%	396
Temperate & boreal forest	15.8%	618	1.5%	50
Tropical forest	19.5%	765	30.6%	1001
Woodland	32.1%	1259	43.5%	1425

Evaluation of the ecosystems economic losses from biomass fires

The Figure 5 shows the variability of evaluation of ecosystems economic values. There are not only variations due to different methodologies, but also due to different locations. This introduces the largest contribution to uncertainties. As stated in the introduction we will not try to hide these uncertainties. These have to be acknowledged as being our current (and insufficient) level of understanding. It shows that much improvements are needed in order to come up with a more refined evaluation. To illustrate the large range of potential losses, values will be provided with minimum, median and maximum evaluations.

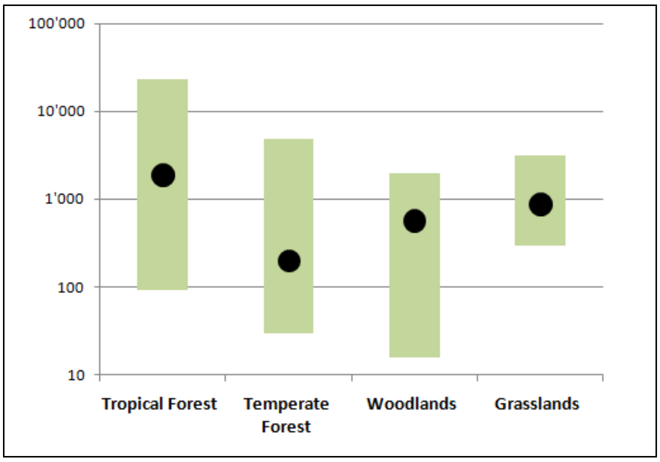


Figure 5 Total of minimum, median and maximum values per biome (units: Int.$/ha/y (2007 equivalent US$ in purchasing power parity (ppp-corrected) , source: Van der Ploeg *et al.*, 2010, p. 26)

Because croplands are mostly burnt after crops were harvested, and the economic value of this biome is not included in TEEB, it was removed from the analysis. The evaluation concentrates on natural ecosystems, it is acknowledged that economic losses from forest converted to cropland, should be reduced by the economic value of cropland. However, this requires more complex approach. In case of slash and burns agricultural practices and in tropical soils, cropland acquired over forest tend to quickly loose yield and may lead to eroded land (with very low economical values). However, this is something that should be more carefully studied in future researches.

The Figure 5 provides the yearly value of an ecosystem. After being burnt, these ecosystems take different length of time to recover. Grass land would quickly recover while tropical forest would take decades to recover. To take into account the intermediate economic losses during the recovering period, the economic losses should be multiplied by half the time of the recovery. E.g. if temperate forests may take 20 years to fully recover, using a linear approach the total cumulative economic loss should be the yearly value multiplied by 10.

Ecosystems	Total recovery (in year)	Value used for cumulative losses
Grassland	1	0.5
Woodland	10	5
Temperate and boreal forests	20 (up to 40)	10
Tropical forest	40 (up to 80)	20

Table 3 Recovery time and factor used for evaluation of cumulative losses

The linear shape and length of ecosystem recovery should be better studied. The values used in Table 3 are gross estimation, however quite conservative.

By combining the value ranges in Figure 5 with the regional burned areas in Figure 4, it is possible to provide a first estimate of the average economic value lost per year (as average) in each region (Figure 6) the maximum values for Africa were truncated in order to use a scale which is more convenient for all the other values.

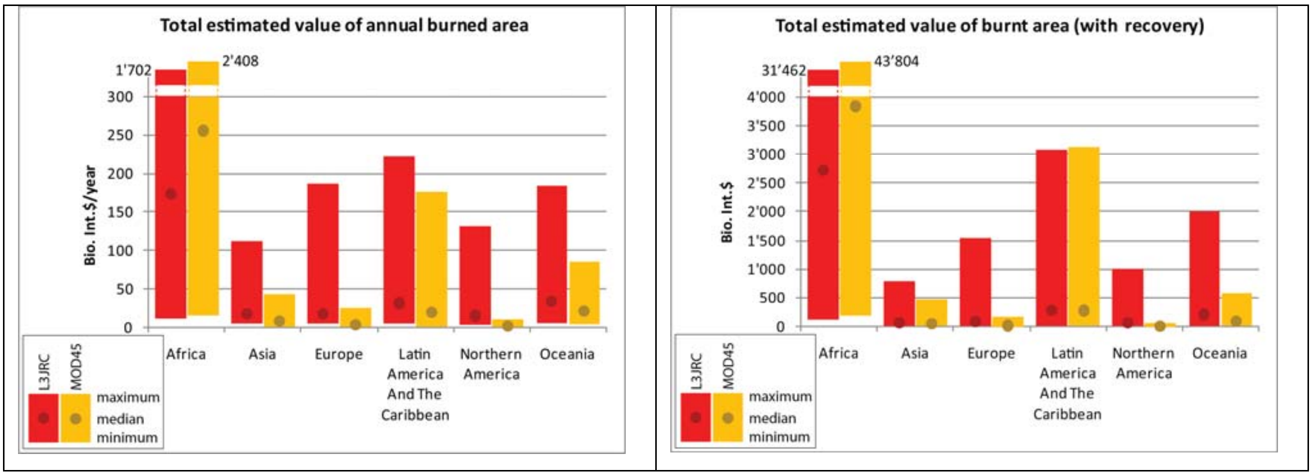


Figure 6 Total estimated of annual burned area (L3JRC ranges are based on the fire seasons 2000-2006, when MDC45 is based on the fire season 2002-2011) with single losses (left) and cumulative losses (right) assuming recovering time as specified in Table 3.

The estimated losses according to L3JRC product would be 291 Billion USD (min. 31.3; max. 2535.1 billion USD) and 308.7 billion USD (min. 23.3; max. 2750.1 billions USD) for MDC45 product. If we consider the median L3JRC product, such amount is equivalent to 2.2 time the global yearly average of reported economic losses from all natural hazard origins calculated over the period 2002 – 2011 (EM-Dat,2012). It is in the order of magnitude of the maximum yearly economic losses ever recorded (363.7 billion US$ in 2011) and higher than the economic losses following the Fukushima earthquake/tsunami/nuclear accident of 2011. At first glance this high value may surprise, however divided by the average area burnt the average economic loss is only 741 US$ per ha, which isn't very high. Knowing that the global value of trade timber in 2000 was estimated to be 400 billion US$ (MEA, 2005) and here we are considering the full range of services (i.e. not only timber production, but also carbon storage, biodiversity, soil protection,…), the value is less surprising. However, this is only the first year losses, given that the ecosystems will take time to recover, the cumulative losses during recovery time should be taken into consideration. This brings values which are hard to grasp. Cumulative losses reach 3.4 trillions USD (min. 178; max. 39.9 trillion US$) per year with L3JRC.

The most sceptical amongst us may want to be more conservative and consider the minimum value,. i.e. minimum values of economic value, without cumulative losses. Even though, the average losses varies between 23.3 and 31.3 billion US$ depending on sensors and would already be 10 times higher than the reported losses by EM-DAT regarding biomass fires, or 17.5% or total reported (by EM-DAT) economic losses from all natural origins. Africa concentrates the highest losses (in absolute) with between 34 and 87.6% of total losses (depending on sensors and scenarios).

The difference between minimum and maximum is smaller on L3JRC (x43) as compared with MCD45 (x240). Still even considering L3JRC, the level of uncertainties is not acceptable, especially given such large economic figures. The margin of errors needs to be reduced at all level.

The need to develop much robust methodology is urgent, so that countries can take into consideration the full range of economic loses and take appropriate actions.

Even if one weakness of the TEEB methodology is, that "*environments have greater value for the rich than for the poor*" (Riechers 2012) and even when using the source with the smallest burned area. The African region median value remains in the same order of magnitude than the maximum value of all other regions. Meaning around 200 billion of USD (the equivalent the economic impact of Great East Japan earthquake and tsunami in March 2011) (EM-DAT, 2012) worth value of land are burned yearly in this single region.

On another scale but still in the same order of magnitude the cumulated value of the median land burned for Oceania, Latin America and the Caribbean is equivalent to the average value of economic damage due to Natural disasters in the Americas (EM-DAT, 2012).

	L3JRC	MCD45

Regions	Minimum	Median	Maximum	Minimum	Median	Maximum
Africa	10.6	173.7	1702.4	15.8	255.1	2408.2
Asia	3.4	17.9	111.2	1.4	8.0	43.8
Europe	3.5	17.5	185.5	0.7	3.6	25.5
Latin America And The Caribbean	3.9	31.8	221.2	1.5	19.4	176.5
Northern America	3.4	15.7	130.9	0.4	1.7	10.2
Oceania	6.4	34.3	183.7	3.5	20.9	86.0
Total	31.3	290.9	2535.1	23.3	308.7	2750.1

Table 4 Estimated mean value of land burned per region without cumulative losses (units: Billion USD 2007 PPP corrected)

	L3JRC			MCD45		
Regions	*Minimum*	*Median*	*Maximum*	*Minimum*	*Median*	*Maximum*
Africa	127.7	2'724.4	31'461.5	179.0	3'837.7	43'804.0
Asia	6.1	72.0	801.0	2.7	48.0	468.2
Europe	10.8	84.5	1'538.3	1.4	13.3	174.4
Latin America And The Caribbean	14.7	289.4	3'072.2	13.0	274.5	3'125.5
Northern America	7.5	63.5	997.4	0.6	5.9	66.5
Oceania	11.3	205.8	1'996.8	4.5	85.5	566.5
Total	178.1	3'439.5	39'867.2	201.0	4'265.0	48'205.1

Table 5 Estimated mean value of land burned per region with cumulative losses (units: Billion USD 2007 PPP corrected)

The large differences between L3JRC and MCD45 values for Northern America, Europe and Asia are probably principally due to an underestimation of MCD45 on these regions. The MCD45 tends to minimize burned areas over North America and Europe while placing most of the emphasis over Africa as compared with L3JRC. This needs to be clarified not only for computation of economic losses but also for GHG emissions. Clearly using MCD45 or L3JRC provides a much different pictures of the relative GHG contribution of the different countries. Given the critical level of sensitivity of these questions, a much more robust level of accuracy and understanding needs to be achieved.

Losses by countries

The top ten countries varies depending on sensors and whether we use minimum, median or maximum scenarios (see Table 6).

	L3JRC			MCD45		
Countries	*Minimum*	*Median*	*Maximum*	*Minimum*	*Median*	*Maximum*
Democratic Republic of the Congo	25	538	6'419	38	813	9'678
Angola	26	543	6'469	38	794	9'382
Zambia	15	321	3'816	21	438	5'182
Central African Republic	14	291	3'406	14	310	3'595
Mozambique	11	224	2'639	16	346	4'079
Sudan	8	192	1'907	13	292	2'861
United Republic of Tanzania	9	200	2'362	11	237	2'770
Australia	11	205	1'992	4	85	565
Brazil	4	93	1'015	8	174	1'976
Chad	3	63	667	4	100	1'008

Table 6 Top ten of countries with the higher absolute median economical lost (average L3JRC and MCD45)

These are absolute economic losses from ecosystems losses. However, to this, already high figures, should be added the recovery costs, as apart from grassland, the ecosystems will take several years to recover. Also, it is interesting to look at these values as a share of national GDP. The problem being that GDP so far do not include ecosystems revenue (except may be a few such as e.g. timber production). So comparing relative losses requires first to include ecosystems services in national GDP and then compute the percentages of GDP lost.

Using Tropical rainforest only

Recognizing that it is difficult to include benefits of biomass fires into the equation as well as to differentiate biomass fires which are usual (either of natural origin, or as part of the ecosystems) from the one ignited by man, we filtered our results using economic losses of tropical ecosystems only. Fires do not belong naturally to tropical forest ecosystems (Cochrane *et al.*, 1999). The study highlights that biomass fires affecting tropical forests only may be leading to economic impacts on ecosystems services (considering median value of the models) in range of USD 146 - 191 billion (different satellite sensors provided different quantifications of burnt area.). However, given that ecosystem services take years to recover (40 or more years) the cumulative annual losses could be as high as USD2.9 – 3.8 trillion. These losses are concentrated in Africa, which concentrates between USD 2.5 – 3.5 trillion a year (Chatenoux and Peduzzi, in prep.). Table 4.1 shows that the losses expressed as percentage of GDP can be extremely high (see Congo DR, Zambia, Central Africa and Mozambique).

However, these figures should be used with caution as the authors of this study have identified several important issues which need to be solved to improve the quality of such assessment. Despite all the caveats identified, it is clear that biomass fires are leading to much more economic losses than initially considered.

Many countries which therefore may be experiencing high losses to natural capital from biomass fires are in Africa. As table 4.1 shows in many of these countries, forest rent makes up a large part of their total wealth and is probably underestimated. These losses to natural capital are rarely taken into account when investment decisions are made that may increase wild-land fire hazard.

Top 10 Countries (ranked according to economic losses from tropical forests)	Estimated Economic losses in Natural Capital in billion US$	Natural capital losses expressed as %age of GDP	Forest rents (% of GDP 2011)
Angola	528.6	5.1	0.2
Democratic Republic of the Congo	524.9	33.5	8.8
Zambia	311.5	32.3	1.6
Central African Republic	276.5	126.0	5
Mozambique	214.3	16.8	2.7
United Republic of Tanzania	192.1	8.0	2.2
Australia	147.8	0.1	0.1
Sudan	143.4	2.2	0.7
Brazil	79.9	0.0	0.3
South Africa	54.3	0.1	0.7

Table 7 Estimated losses of natural capital in tropical rainforest ecosystems from biomass fires in absolute, relative to GDP and forest rents in proportion of GDP.

Data sources: rank and economical losses percentage of GDP losses (Chatenoux and Peduzzi, in prep.), GDP, forest rent (World Bank, 2011)

The next phase would be to solve some of the gaps identified in order to reduce the uncertainties as well as to extend the research to the other ecosystems. However, these preliminary findings reveal that even focussing on tropical ecosystems only, the estimated economic losses are much larger than the reported losses.

Conclusions

This study shows that improvements are needed at all steps. The low agreement between the two global burnt areas needs to be properly assessed to identify which one is the best products and if there are ways for reducing both omission and commission errors. Secondly, the difference between minimum and maximum value of ecosystems should be reduced. So far the maximum value is between 10 and 255 times higher than the minimum [tropical forest (255); temperate forest (162); woodlands (122); grasslands (10)]. Models using spatial analysis can help in improving the value of ecosystems, by introducing local revenue, distance from urban centres to improve evaluation of ecosystems services. One can understand that the recreational value of a forest has greater value close to a high-end touristic location as compared to isolated location, while carbon storage should have the same value everywhere.

Despite the large range of uncertainties, even considering conservative approach, the economic losses values remains at levels equivalent to large natural hazard events or regional to global annual level of economic losses. Highlighting, if necessary, that annual wild fires remain a hidden, significant economic loss on ecosystems and biodiversity which needs to be better evaluated. This analysis, even if limited in its accuracy (and which should be considered as a work in progress), is the first attempt and allow to identify a number of key points which need to be improved in order to simply start evaluating properly the economic impacts of this hazard.

The estimation of burned areas, even if well correlated at global scale, show inacceptable variations at regional scale. Consequently a special effort will be necessary to define one single source (or a regional mix of several sources) through literature review or the use of a limited number of biomes compatible with LCCS terminology and at a regional scale. The second but, main issue is to precise the economic value of a limited selection biome taking a regional approach.

A proper inclusion of cultivated land in the analysis should decrease the difference between Africa and highly cultivated regions such as Asia, Europe and Latin America. Also, using rainforest only, was only a temporary solutions. Ideally, we would need to take into account the natural occurrence of biomass fires in the other ecosystems and include potential economic benefits if biomass fires.

Regardless of the numerous identified caveats, this preliminary analysis shows that the level of economic losses from burnt ecosystems is colossal and has failed to be addressed so far in other global assessments. It should raises the profile of biomass fires hazard in the overall concerns for disaster risk reduction to be more at pair with other usually main hazard (flood, tropical cyclones, drought and earthquakes).

Recommendations for future researches

Given the low agreement between the two burnt areas products (L3JRC and *MCD45*), both commission and omission errors need to be reduced. This is an area of research which should be encouraged. The choice of one or both products has drastic consequences which needs to be better understood.
Using both GlobCover 2005 (*GC05*) and 2009 to improve quality of burnt areas, e.g. by creating annual dataset using these two dataset. Forest or woodland areas which have been identified as burning several times, should be considered as grassland for the next 5 years, woodland for the next 10 years.
Address the issue of economic value from cropland, when forest (or grassland) are converted to cropland. Should look at short, medium and long-term impacts on ecosystems services from such conversion.
The linear function and length of ecosystem recovery should be better studied for improving cumulative losses.

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