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Mapping certified forests for sustainable management - A global tool for information improvement through participatory and collaborative mapping

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ABSTRACT

There are currently no spatially explicit, openly accessible data available on forest certification below national level, so understanding the drivers of certification in the past, examining the scope for further certification and using this information for development of future sustainable forest management strategies is challenging. Hence, this paper presents a methodology for the development of a global map of certified forest areas at 1 km resolution in order to satisfy this information need. Validation of the map with certified areas in Russia showed reasonable results, but the lack of openly accessible data requires broadening the strategy for improving the global certification map in the future. Thus, the second aim of the paper is to present an online tool for visualization and interactive improvement of the global forest certification product through collaborative mapping, aiming at a range of stakeholders including third-party certifiers, green NGOs, forestry organizations, decision-makers, scientists and local experts. Such an approach can help to make more accurate information on forest certification available, promote the sharing of data and encourage more transparent and sustainable forest management, i.e. both producers and users can benefit from this online tool.

1. Introduction

Forests are the host to very different uses such as timber production, recreation, habitats for biodiversity, water management and animal husbandry, and in some places, are subject to the rights of indigenous people and local communities. Clearly, there will be interactions between these different uses, potentially causing tradeoffs if occurring in the same place. To capture and balance all of the different services and uses of a forest, the concept of sustainable forest management was developed. Sustainable forest management has multiple objectives and is of vital importance for various Sustainable Development Goals (SDGs, e.g. SDG 15 on "Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, halt and reverse land degradation, halt biodiversity loss"), and for the greenhouse gas balance among many other benefits. The failure of the United Nations Rio Summit to agree upon a sustainable forest convention inspired the first private certification schemes, which began in 1993 (Rametsteiner and Simula, 2003). Subsequently, forest certification was supported by environmental groups to address concerns about deforestation and forest degradation and to promote the maintenance of biodiversity. From there, forest certification has developed into one type of tool for the implementation of sustainable forest management. Many certification schemes have since emerged, where the Forest Stewardship Council (FSC) and the Programme for the Endorsement of Forest Certification (PEFC) are the two most prominent private schemes.

In May 2014, these certification schemes reported a total gross area of 440.3 million ha (Fig. 1) under their individual (endorsed) certification standards. The PEFC has endorsed 258 million ha of certified forest land in 28 countries, whereas the FSC has certified a total of 182 million ha in 81 countries (Fernholz et al., 2014). This certified forest area has become an important indicator for many assessments. The revised set of indicators under Forest Europe (Pan-European

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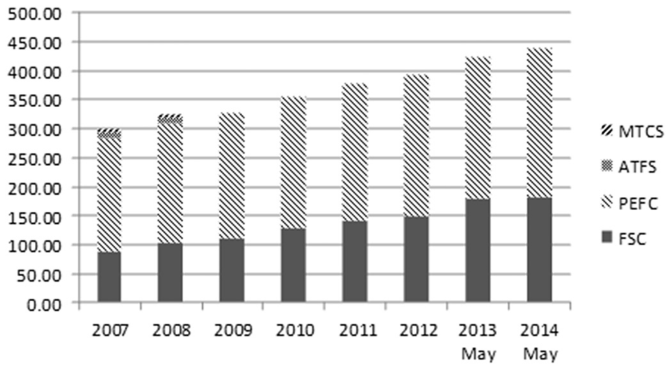

Fig. 1. Forest area certified by major certification schemes 2007–2014, in million hectares by year and scheme. Note that MTCS and ATFS have been endorsed by PEFC in 2008 and hence are accounted under PEFC since 2009.
Source: modified after Fernholz et al. (2014).

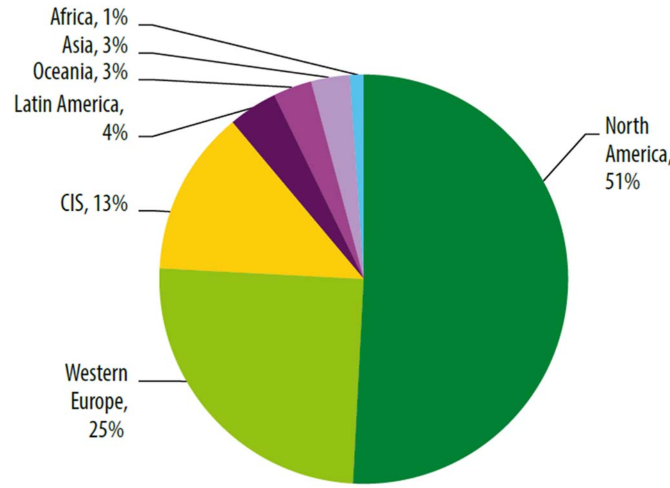

Fig. 2. Total certified forest area by regional share (2014).
Source: modified after Fernholz et al. (2014).

Region), for example, includes one on certified forest area (Linser and Wolfslehner, 2015). Other bodies considering certified forest areas include the Biodiversity Indicators Partnership (BIP), which serves the global user community by responding to the indicator requests of the Convention on Biodiversity (CBD) and other biodiversity-related monitoring and reporting efforts such as IPBES (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services) (BIP, 2017).

Although the amount of certified forest area has increased almost exponentially during the last decade, about 90% of the globally certified area is located in the northern hemisphere (Fig. 2). This indicates the success of forest management certification in Europe and North America but also shows that certification schemes have still not become widely established in the southern hemisphere (Karmann et al., 2009),[1] although good examples of sustainable forest management in the pursuit of FSC certification exist, e.g. the Congolaise Industrielle des Bois (CIB) in the Republic of Congo.

Karmann and Smith (2009) and Romero et al. (2013) provide comprehensive literature studies on the question of certification effects, where the latter also cover stakeholder views. The authors of both studies found that most literature they reviewed was based on geographically limited case studies, anecdotal evidence, or studies that were not conducted by independent observers. More importantly, they concluded that there is insufficient empirical evidence regarding the impact of certification at a *global* scale and hence more studies of the impact of certification are needed. More recently, Heilmayr and Lambin (2016) showed that FSC certification schemes were more effective in slowing the conversion of forests to other types of land use compared to other market-driven governance approaches in Chile, although the results are only for one country.

In general, there is only very limited statistical data publicly available and readily accessible for carrying out empirical studies to assess the past, present and future development of certification, even though the information in principle exists, at least in the case of FSC. The United Nations Economic Commission for Europe, together with the Food and Agriculture Organization of the United Nations (UNECE/FAO), provides the only official and independent data repository for forest management certification, bringing this information – inter alia from FSC – together; see e.g. the Forest Products Annual Market Review (e.g. Fernholz et al., 2014).

Publically available data from the FSC (2014) and PEFC (2014) can be accessed at an aggregated, national level only, which are plotted in the upper and lower panels of Fig. 3, respectively. Yet there are a multitude of uses for spatially disaggregated data on certified areas for different groups: researchers can combine the data with other spatially explicit information, e.g. on concessions, protected areas, landscape restoration options and economic variables in their global models to investigate questions of interactions, economic incentives and opportunities, and policy scenarios (e.g. Kraxner et al., 2009). Others have pointed to the need for such maps for transparency and credibility reasons (cf. "Transparent Forests" project by FSC, CIFOR and WRI and the Global Forest Watch initiative of WRI and more than 50 organizations). Finally, NGOs can overlay this information with their data on environmental and social indicators, facilitating the monitoring and identification of action needs such as counseling.

In the UNECE/FAO publication series, Kraxner et al. (2008) published the first spatially explicit global forest management certification map (Fig. 4), integrating indicators from FSC and PEFC based on findings by Rametsteiner and Simula (2003). While this map represents a major step in the right direction with respect to the spatial analysis of certification, there is clearly scope for further development, which is the main objective of this study. It is important to note that an evaluation of why and where forests are certified or not can be done with the current publicly accessible information on certification. However, how this can be done is not yet clear and the contribution of this paper is to offer a new methodology to fill this gap. Using a globally consistent approach, we applied a downscaling algorithm to distribute forest management certification areas spatially, which will provide a better representation of where certified forests are located globally. The second objective is to share this information using the interactive online crowdsourcing platform called "Geo-Wiki"[2] (Foody et al., 2014; Fritz et al., 2012; Fritz et al., 2009; Schepaschenko et al., 2015; See et al., 2015). Crowdsourcing is the outsourcing of microtasks to citizens, which includes data collection, analysis, hypothesis generation and opinion gathering, among others (Howe, 2006). The Geo-Wiki platform is used here in two ways: a) as a visualization tool so that the forest certification map and the input data can be viewed and b) as a participatory and collaborative mapping tool so that different users (e.g. scientists, public and private investors, certification schemes) can validate and improve the map using the interactive feedback and collaborative mapping tools within Geo-Wiki[3].

[1] Even though the total FSC-certified area in the tropics exceeds 10% of the global FSC-certified area, the number of certificates (1 out of 4) in the tropics gives a more accurate impression of this discrepancy (FSC, 2017).

[2] Geo-Wiki is a platform that provides citizens with the means to engage in environmental monitoring of the Earth by providing feedback on existing spatial information overlaid on satellite imagery or by contributing entirely new data. Data can be input via the traditional desktop platform or mobile devices. Resulting data are available without restriction (www.geo-wiki.org).

[3] For instructions on how to use the Geo-Wiki tool and how to provide feedback in order to improve the global certification map, please see: https://geo-wiki.org/archive/manual/feedback_forest_certification.pdf.

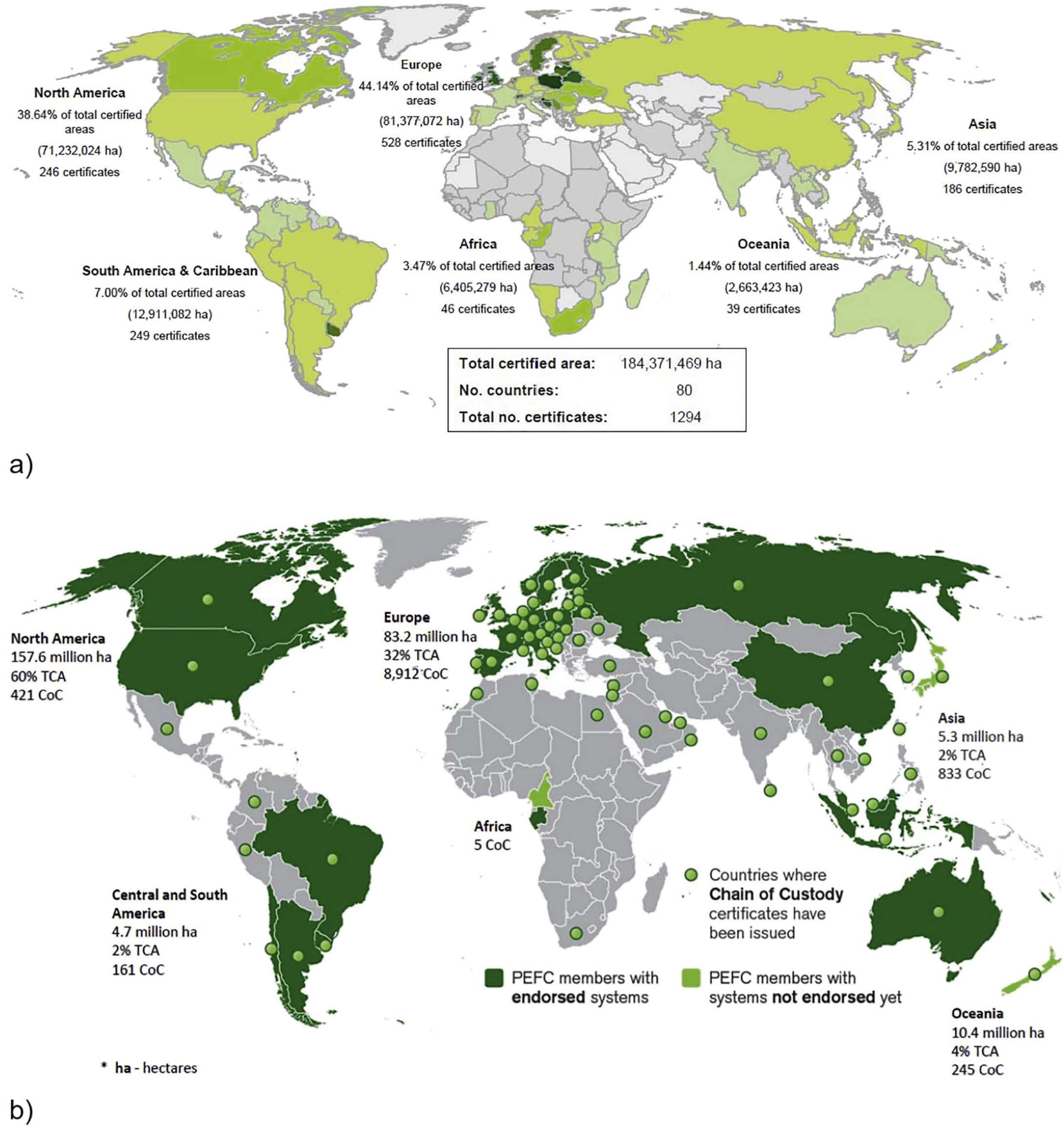

Fig. 3. Global certification map by FSC (a), indicating the relative shares of certified forest area with the help of a light green color ramp. Global certification map by PEFC (b), indicating certification shares of countries (numbers) and membership status (darker green color ramp). Data for the year 2015 are also available at the respective websites. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)
Source (FSC, 2014; PEFC, 2014).

2. Materials and methods

As input data we used the recent FSC (2014) and PEFC (2014) data for forest management certification at the national level. In addition, sub-national data for Russia were obtained by administrative region (for 81 provinces) from FSC Russia (FSC personal communications, 2014). The downscaling of national (and sub-national) certified area statistics was then carried out following a number of steps as outlined in Fig. 5.

The first step was to delineate the forest area itself (Fig.5, step 1). For this purpose, we selected the hybrid forest mask produced by Schepaschenko et al. (2015), which has a number of advantages including the fact that it is based on a multi-sensor remote sensing approach, is consistent with FAO-Forest Resources Assessment (FRA) statistics (and therefore the FAO definition of forest) and has a resolution of 1 km, which is the same resolution at which the forest certification map is produced. The protected areas of the International

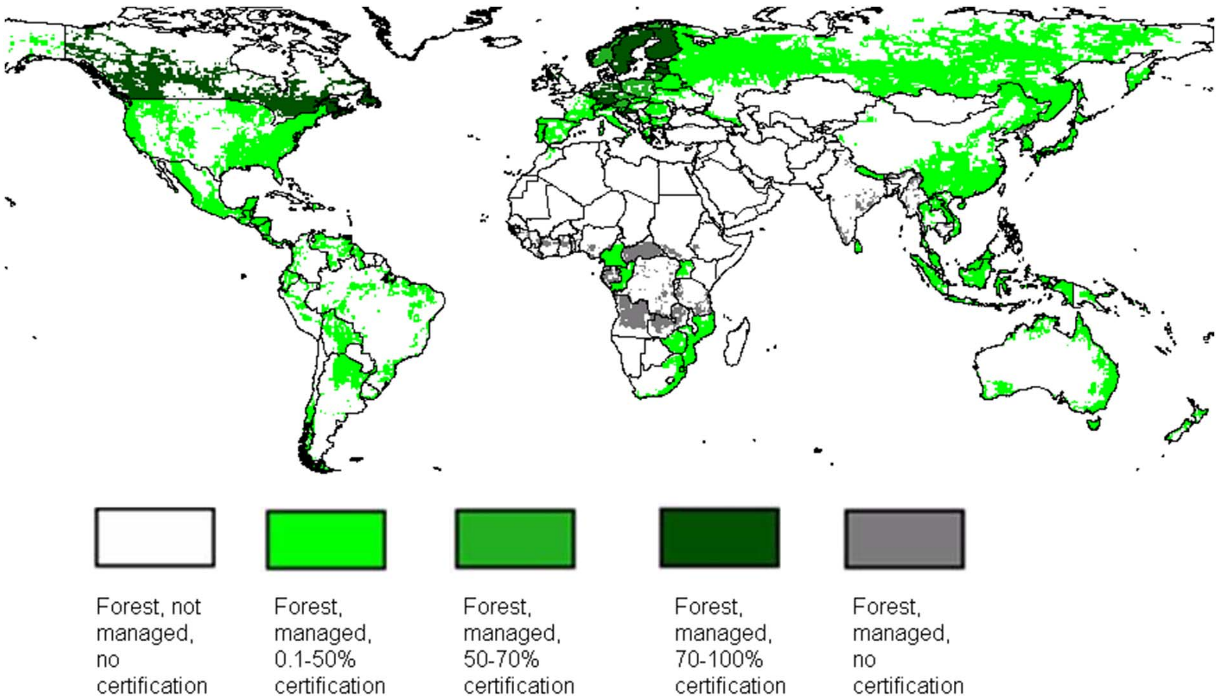

Fig. 4. Forest area certified (%) relative to the forest area under management (min. 10%) by countries.The green shaded areas represent the different levels of certification (% of national managed forest certified) increasing with color intensity. Source: modified after Kraxner et al. (2008). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)
Input data: ATFS (2008), FSC (2008), PEFC (2008), FAO/FRA (2005), CIESIN/HII (2005) for downscaling.

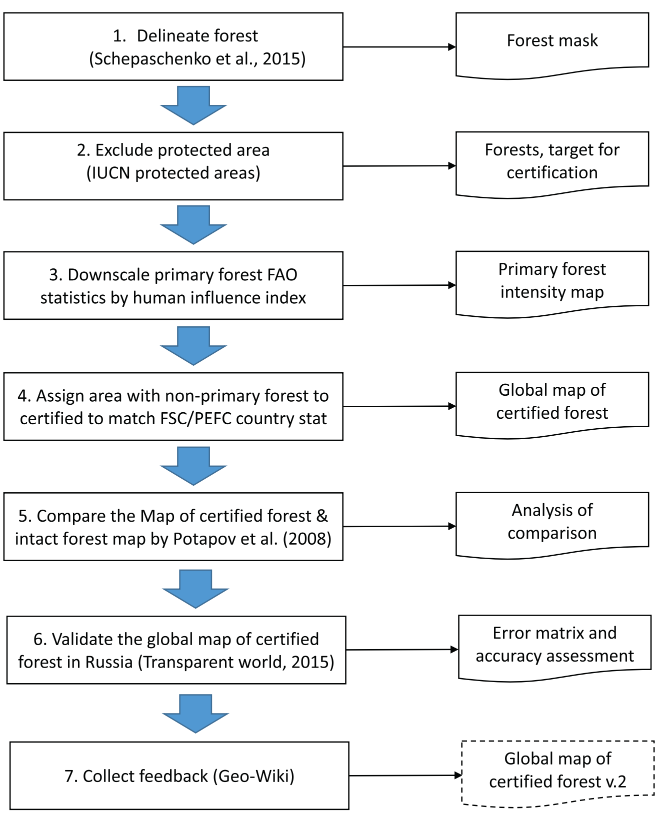

Fig. 5. A flowchart of the methodology used to create and validate the new global certified forest area map: steps (left) and intermediate/final results (right).

Union for Conservation of Nature (IUCN) categories I–II (IUCN and UNEP-WCMC, 2015) were then overlaid onto the forest mask in order to remove these areas from the analysis (Fig. 5, step 2), leaving only forest areas with a higher probability of having certified areas.

Another key input to the algorithm is the location of primary forest (Fig. 5, step 3), where we used the FAO definition (FAO FRA, 2010) of naturally regenerated forest of native species, where there are no clearly visible indications of human activities and the ecological processes are not significantly disturbed. Primary forest area at the country scale is reported in FAO FRA (2010). To create a spatially explicit map of intensity of primary forest (on a scale of 0 to 100%) at a 1 km resolution, we used the global map of the human influence index (HII) (on a scale of 0 to 100%) produced by Sanderson et al. (2002) as an input. We assumed that any grid cell that has forest based on the forest hybrid mask and a HII of zero contains 100% primary forest. We then needed to determine the % primary forest for cells where the HII is greater than zero and has forest based on the forest hybrid mask. Thus for each country, we determined a threshold value of the HII such that the remaining primary forest reported by the FRA 2010 was allocated to grid cells containing forest cover, using the following equation:

$$\%\text{primary forest} = 100–100*\text{HII}/\text{Threshold}$$

Values of HII that were greater than this threshold were then assigned 0% primary forest. For 14% of countries in the world, which together represent less than 6% of the global forest area, there is no primary forest reported in FRA 2010. For these countries, a global average threshold for the HII was calculated. This global average was then used to allocate primary forest to those countries with missing data.

The next step in the methodology (Fig. 5, step 4) is to spatially distribute the forest certification statistics at the national level to a 1 km resolution using the primary forest map produced in step 3 as an input. We assume that forest management and forest certification have primarily occurred in non-primary forests that are most influenced by humans. We use a downscaling algorithm similar to that which was used to create the global hybrid cropland (Fritz et al., 2015; Fritz et al., 2011) and the global forest (Schepaschenko et al., 2015) map products. The procedure distributes forest certification starting with those pixels that have the lowest share of primary forest, continuing until the covered area matches the national and sub-national forest certification statistics from FSC and PEFC. In this way, we produced a global map of certified forest that is consistent with certification statistics at the country scale.

Finally, we made some preliminary verification of the map (Fig. 5, step 5) and compared the global forest certification map with a map of intact forests from Potapov et al. (2008), where they define intact forest as the unbroken expanse of natural ecosystems within the zone of current forest extent, shows no signs of significant human activity, and is large enough to maintain all native biodiversity. Validation was then undertaken (Fig. 5, step 6) using an FSC-certified forest map of Russia as of June 2015 (Transparent World et al., 2015). Although we acknowledge that Russia is not the most representative country in terms of population density, forest ownership, the size of the management units and the low level of certification (9% of forested area) compared with other countries that have large forests, it is, nevertheless, the only country where spatially disaggregated data were available for comparison with our product. The results from the verification and validation exercises of the spatial forest certification product are described in detail in the results section.

In the final step (Fig. 5, step 7), we shared the map on Geo-Wiki (http://forest.geo-wiki.org) so that users (i.e. researchers, certification schemes, forestry companies, NGOs, etc.) can view it and provide feedback using the interactive, collaborative mapping tools[3].

3. Results

Since we are assuming that most of the globally certified forest area coincides with managed forest, a major component for distinguishing between managed and unmanaged forest is the identification of primary forests. Our primary forest intensity map, based on the methodology outlined in the previous section, is shown in Fig. 6. It demonstrates that the largest areas with high primary forest intensity are located in the tropical basins of the southern hemisphere, i.e. mainly in Brazil and Indonesia, and in the vast boreal zones of the northern hemisphere, i.e. mainly in Eurasia and North America. This dataset has also been used recently to estimate woody biomass energy potential (Lauri et al., 2014).

After applying the downscaling algorithm described in the methodology to allocate certified forest areas based on the primary forest intensity map (Fig. 6), a new global high-resolution certification map was generated as shown in Fig. 7. The results show that all non-primary forests in Canada and Scandinavia are certified. The rest of Eurasia and the USA are less covered by certified forest. Russia and its vast boreal forest areas in Siberia as well as large parts of China and Mediterranean Europe show the largest area of currently uncertified forest and thus high potential for future forest certification in the northern hemisphere, even though the actual potential will also depend on the quality of management.

As a first qualitative verification, we compared the new certification map with the map of intact forests developed by Potapov et al. (2008) to determine if they coincide in area. The assumption was that intact forests are not certified because they are remote areas (correlating with low economic value and inaccessibility), protected areas or both. Certification of intact forests might represent prospective information on areas that could be converted from unmanaged to managed (and certified) forests. Fig. 7 shows that the core zones of primary forests (corresponding to intact forests) are free of any certification. Only for Canada can some overlap between intact and certified forest areas be observed. This finding is supported by the fact that the major certification schemes (i.e. PEFC) are mostly certifying managed forests although not exclusively.

Since spatial information on forest management certification for public use is extremely scarce, we used the only spatial dataset that is publicly available, which is the map of FSC-certified forest in Russia as of June 2015 (Transparent World et al., 2015). The latter can be considered as "ground truth" with the following caveats: 1) FSC-certified forest area represents 98% of all certified area in Russia. This means that the area certified by FSC is equal to the total certified area (by all schemes) in Russia; 2) the FSC map for Russia refers to 2015, while the base year for the new global certification map is 2014; and 3) it is only available as a Web Map Service (i.e. not directly usable in a GIS). The conversion of this map into a GIS usable format introduced a spatial error of 10 km on average, which is negligible given the size of Russia (~10,000 × 4000 km). However, to reduce the spatial error as much as possible, we aggregated both the global forest certification map (only

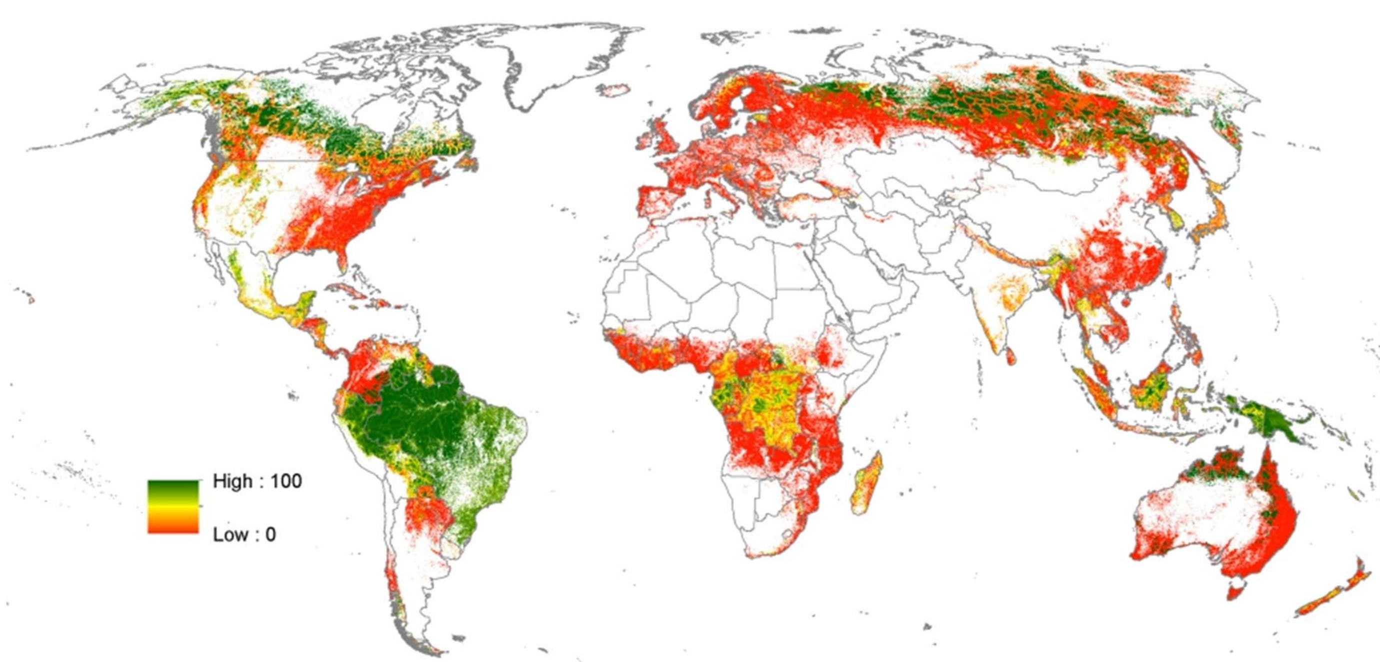

Fig. 6. Primary forest intensity map, representing primary and non-primary forest extent and share for each 1 km pixel in %. While green colors correspond to the area dominated by primary forest, the red colors indicate the dominance of non-primary forests. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

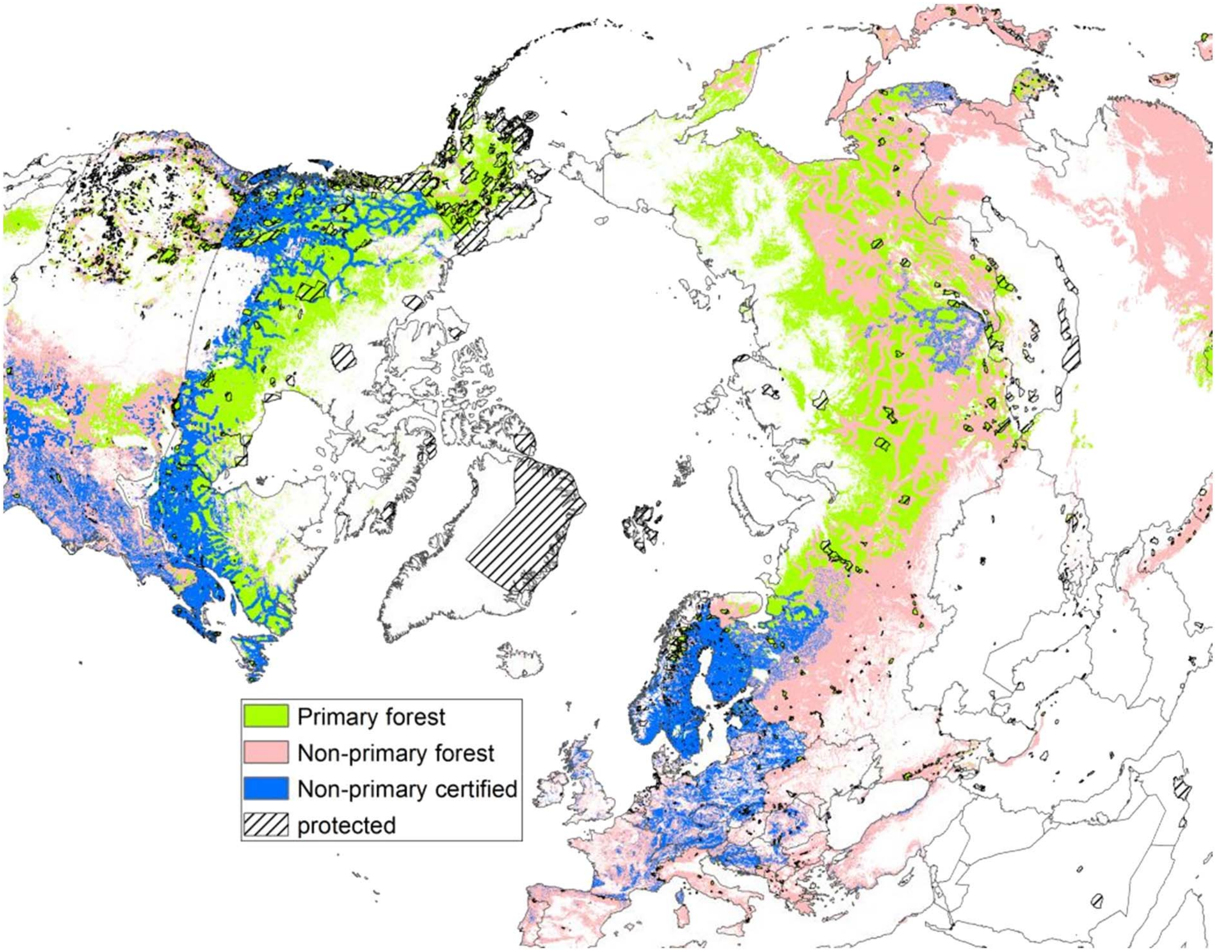

Fig. 7. High resolution global certification map, displaying the northern hemisphere, with 4 color-coded categories of forest (primary, non-primary, non-primary certified, protected) at a 1 km resolution. White areas are none-forested areas or the sea/water bodies.

Table 1
Error matrix for two maps of certified forest in Russia, %.

New global forest certification map	Map by Transparent world (reference dataset)			User's accuracy
	Not certified	Certified	Total	
Not certified	80.1	3.6	83.7	95.6
Certified	7.4	8.9	16.3	54.9
Total	87.4	12.6	100.0	
Producer's accuracy	91.6	71.0		

for the Russian part) and the FSC map for Russia to a 100 km grid and calculated the percentage of certified forest. The result is that forest is represented in 1700 grid cells. Our new global map indicates that 277 grid cells contain certified forest in Russia, while the FSC map of Russia (Transparent World et al., 2015) shows certified forest in 214 grid cells. The error matrix resulting from a comparison of these two maps is shown in Table 1.

The overall accuracy and alternative chance-corrected accuracy (Gwet, 2002) show reasonable results (AC = 89%, AC1 = 85%). The new global forest certification map correctly captures 71% (Producer's accuracy of certified class – 152 grid cells out of 214) of the certified forest represented in the FSC map of Russia (Transparent World et al., 2015). Certified forests in our new map are slightly more widespread over the territory (16.3%) compared to the FSC map of Russia (12.6%), which explains the relatively lower user's accuracy of 54.9%. This validation result is very good considering that only 9% of the Russian forest area is certified (or 13% of forested grid cells are partly certified). Although one can expect much better agreement in countries with higher levels of certification (e.g. Nordic countries or Canada, where most of the managed forest are certified), these datasets are not currently publicly available.

4. Discussion and outlook

In this paper, a new method has been developed to create an openly accessible, spatially explicit map of certified forest area at a 1 km resolution, which is based on the fusion of different sources of information, including country statistics and remote sensing products. The validation process showed a large area of agreement between the global forest certification map and spatial data provided by FSC for Russia. While the results of the validation are very encouraging, we recognize that there are a number of potential sources of error. First there is uncertainty regarding how much forest is certified (or not), so the national numbers are only an approximation. Although it is possible to find information about certified units from the (FSC) ownership/certificate holders online at info.fsc.org, it is much more challenging to find information about who the owners or contact persons are for uncertified forest areas.

Secondly, the data from FSC and PEFC are not up to date in the sense that forests are reevaluated, uncertified and recertified in a dynamic process, so the map will only ever be a snapshot in time, in this case for a single year: 2014. Extending the analysis to other years to create a time series of spatially explicit global forest certification maps could be a very valuable resource for researchers.

Third, the downscaling process also adds some uncertainty, since it

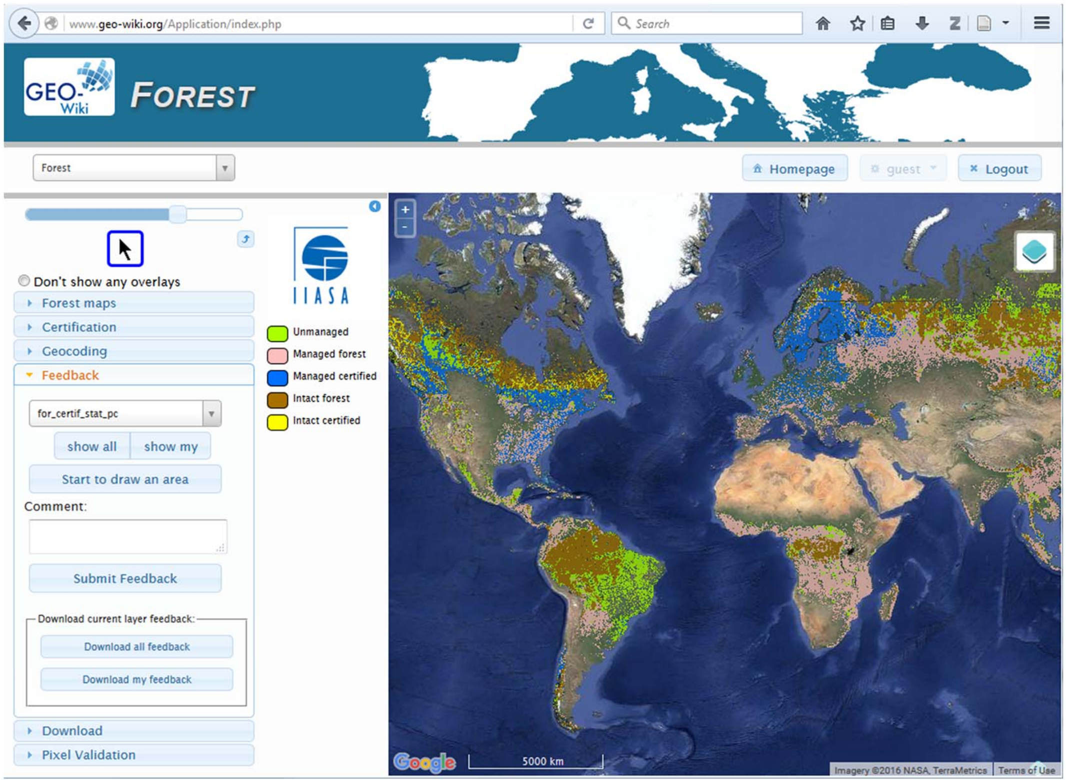

Fig. 8. Screen snapshot of the Geo-Wiki on-line tool aiming inter alia to present this first global forest certification map and to collect feedback.

is a theoretical approach based on where the most suitable areas are for certification rather than being based on ground truth data. The human influence index is also based on assumptions related to population density, distance from roads, etc., which may not capture all areas of human influence and hence affect which areas are considered suitable for certification.

Finally, statistics show that about 10% of managed forests were certified by 2015 (FAO, 2012a). This might significantly underestimate the importance of certification, however, as there is also unproductive forest area in the total sum. Yet, it is very difficult to define productive forestland: for example, “forest with a management plan” is too broad a definition, which includes forest area in protected areas. “Production forest”, on the other hand, is too narrowly defined and does not include forest area designed for multiple uses. In addition, the statistics from some countries are weak. Still, looking at production forest gives us a 39% share of certified area according to the FAO definition (FAO, 2012a), exceeding the 10% share for managed forest by far. This indicates that further improvements in the mapping of certified forests will also contribute to a more precise valuation of the importance of certification in the first place.

The main problem remains that the validation so far is extremely limited, since either the ground truth data do not exist in a usable form (e.g. some of the data refer to the location of the companies rather than the location of the certified forests or the absence of digitized certified forest areas) or the data do exist but are not openly shared. In some cases, the data in the FSC database are point locations of certified forests, where a buffer around the point could be used to add some spatial information to the map. This will be investigated in more detail as part of future research. However, to help improve the global forest certification map in the absence of such data, a participatory and collaborative mapping approach has been implemented in the Geo-Wiki online tool (http://Forest.Geo-Wiki.org). As well as visualization of the global forest certification map (at a 1 km resolution), users are encouraged to share any existing spatial information on certified forest areas by drawing these onto the current map, sharing any existing maps or by highlighting areas that are incorrectly represented as certified areas using the feedback tools embedded in Geo-Wiki (Fig. 8). The potential users of such a system include: certification schemes and bodies, certificate holders, third-party certifiers, green NGOs, forestry organizations, relevant decision-makers and scientists. For example, forest managers might feel invited to check if their certified forest area is in the right location and to correct this information, when appropriate. We plan to actively engage these stakeholders, e.g. through targeted campaigns, in order to elicit feedback and move towards an improved community-based global forest certification map as a co-produced and freely available product.

For a user guide on how to participate in the improvement of the new global forest certification map through Geo-Wiki, please refer to the Geo-Wiki website (http://www.geo-wiki.org/branches/forest/ and https://geo-wiki.org/archive/manual/feedback_forest_certification.pdf).

5. Conclusion

The literature review identified the lack of high-resolution forestry certification statistics as the main limitation for different user groups. The benefits of providing such a map at a global scale differ among those groups, with a clear gain for certification bodies for their auditing and other activities. By enabling an analysis of the status quo, hot spot areas can be identified, which can help raise to awareness and provide support. In addition, private and public investors, NGOs and donors can use this information for their own assessment and planning of further courses of action. In this way, the currently slowing trend of certification (Fernholz et al., 2014) and its concentration in the northern hemisphere might be altered in the future. For example, we are aware of current initiatives, both by FSC and PEFC, to increase forest certification in the tropics (e.g., this has been highlighted at the 7th FSC General Assembly in 2014, http://ga2014.fsc.org). Certifying a larger area in these regions could lead to significant impacts on prices and environmental governance (Cai and Aguilar, 2013; Forrer and Mo, 2013; Tully and Winer, 2014).

Perhaps less obvious, but nevertheless important, are the potential benefits to policymakers, e.g. in the coordination of environmental agreements. Once a map of currently certified forest area is available, it can be combined with other geographically explicit information, e.g. identifying areas with large co-benefit potential, in order to form targeted policy strategies. The latter could foster, for example, sustainable biomass for bioenergy production, the assessment of landscape restoration options - e.g. under the Bonn Challenge[4], biodiversity conservation or Reduced Emissions from Deforestation and Degradation (REDD +) activities (Angelsen et al., 2015; cf. Kraxner et al., 2011). This is only possible if such tools are further developed and applied at the science-policy interface. Moreover, when updated and further developed, the map and database will be a good basis for conducting empirical studies on the impacts of certification at a global scale, as an answer to the call by Romero et al. (2013). Adding a temporal dimension will allow for studies such as that undertaken by Heilmayr and Lambin (2016), which determined the effects of different market-based governance schemes, including FSC, on slowing forest conversion, but at a global scale rather than only for a single country. Such tools are also important for monitoring of compliance of activities of certified organizations with the standards and policies of the certifying institutions, particularly in large forest countries such as Russia (FAO, 2012b; Laguns, 2009).

While we recognize that the nature of benefits varies across user groups, they are inherently interconnected. For example, maps of certified forest can be used as a marketing tool and for monitoring by certification schemes, the private sector and governments. Although beyond the scope of this study, such an analysis and its quantification could be the subject of future research. A better common information base might also improve public-private partnerships, leading to increased certification in the tropics (cf. Gulbrandsen, 2014). Moreover, the data could be useful for studying the influence of certification on illegal logging (Kishor and Lescuyer, 2012), forest degradation (Brandt et al., 2016) and to study the effects of certification on indigenous peoples' rights (Teitelbaum and Wyatt, 2013). Finally, a spatially explicit representation of current and potentially certified areas could be used to consider locally and regionally specific conditions for adaptive forest management (Duinker and Trevisan, 2003).

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