Harnessing the Power of Volunteers, the Internet and Google Earth to Collect and Validate Global Spatial Information using Geo-Wiki

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Highlights of the Paper

1. Geo-Wiki is a tool for visualisation, crowdsourcing and validation of information on global land cover.

2. Recent enhancements to the tool include a Geo-Wiki for teaching, mobile phone apps and gamfication.

3. Crowdsourced data from Geo-Wiki have been used to create new maps of agricultural field size, wilderness, cropland and land cover.

Abstract

Information about land cover and land use is needed for a wide range of applications such as nature protection and biodiversity, forest and water management, urban and transport planning, natural hazard prevention and mitigation, monitoring of agricultural policies and economic land use modelling. A number of different remotely-sensed global land cover products are available but studies have shown that there are large spatial discrepancies between these different products when compared. To address this issue of land cover uncertainty, a tool called Geo-Wiki was developed, which integrates online and mobile applications, high resolution satellite imagery available from Google Earth, and data collection through crowdsourcing as a mechanism for validating and improving globally relevant spatial information on land cover and land use. Through its growing network of volunteers and a number of successful data collection campaigns, almost 5 million samples of land cover and land use have been collected at many locations around the globe. This paper provides an overview of the main features of Geo-Wiki, and then using a series of examples, illustrates how the crowdsourced data collected through Geo-Wiki have been used to improve information on land cover and land use.

Keywords: land cover, land use, crowdsourcing, volunteered geographic information, validation

1 Introduction

The last fifteen years have seen radical changes in our technological environment. We have computers that are now capable of both faster information processing and storage of much larger datasets than ever before. At the same time our experiences online have become much more interactive due to the advent of Web 2.0. The steady democratization of information has meant open access to high resolution satellite imagery, e.g. through Google Earth, and the ability to view and download openly available, authoritative data from mapping and other government agencies. Moreover, our online environment has been subject to other changes as we move increasingly to mobile devices for information and data collection. These changes together have culminated in the rise of crowdsourcing and the citizen as a sensor of information. Crowdsourcing is the umbrella term for involving the crowd in activities that would not be possible with the limited resources of most organizations (Howe, 2006). When crowdsourcing is used to refer specifically to spatial data collection, then volunteered geographic information or VGI is often employed (Goodchild, 2007). As a result of these aforementioned changes, citizens have become transformed into neogeographers, as described by Turner (2006) in his book 'Neogeography', i.e. the developers of their own maps, as they generate content online and begin to blur the boundaries between traditional map producers and consumers of this information (Haklay et al., 2008). OpenStreetMap is a prime example of a community of citizens that are interested in mapping their environment and opening up access to the data as a collective, social contribution. Many parts of the world have already been mapped and navigation applications have been built around this dataset.

Another example of a thriving VGI community is the one built up around Geo-Wiki, which was born out of the need to improve global land cover data. Information about land cover and land use is needed for a wide range of applications such as nature protection and biodiversity, forest and water management, urban and transport planning, natural hazard prevention and mitigation, monitoring of agricultural policies and economic land use modelling. A number of different remotely-sensed global land cover products are available but studies have shown that there are large spatial discrepancies between these different products when compared (Giri et al., 2005; McCallum et al., 2006; Fritz et al., 2011a). Geo-Wiki was developed to address this issue of land cover uncertainty. Geo-Wiki integrates online and mobile applications, high resolution satellite imagery available from Google Earth, and data collection through crowdsourcing as a way of improving spatially relevant information on land cover and land use. Through its growing network of volunteers and a number of successful data collection campaigns and gaming, almost 5 million samples of land cover and land use have been collected at many locations around the globe. Other land cover validation tools exist such as VIEW-IT (Clark and Aide, 2011) and the land cover validation tool developed for Important Bird Areas (Bastin et al., 2013) but these tools were designed more for expert-sourcing and are not currently open to the crowd.

An overview of Geo-Wiki has been provided previously in Fritz et al. (2009, 2012), where these papers have focussed on the Geo-Wiki concept and more technical details such as the architecture and the initial crowdsourcing efforts that were undertaken. In contrast, this paper serves to highlight the new developments in Geo-Wiki that have occurred since these two previous works were published. With several successful crowdsourcing campaigns undertaken and the move to a mobile and gaming environment, Geo-Wiki is becoming a more flexible tool, moving beyond its original conceived purpose. After outlining the main features of Geo-Wiki, examples are provided to illustrate how Geo-Wiki has led to both the improvement of global land cover and resulted in the development of several new products such as maps of agricultural field size, wilderness and cropland. Finally, we outline ongoing and future developments in the Geo-Wiki technology.

2 The Geo-Wiki Tool

Geo-Wiki is a visualisation, crowdsourcing and validation tool for improving global land cover information, as outlined previously in Fritz et al. (2009. 2012). In addition to the main Geo-Wiki website (http://www.geo-wiki.org), there are many thematic branches. Some of these branches are accessed by modifying the web address, e.g. biomass.geo-wiki.org, while others can be selected directly from inside the latest version of the application.

Although Geo-Wiki was originally an online tool, mobile applications have now become available. More recently, Geo-Wiki has been extended to the classroom and is being used as a teaching tool. Finally, we have investigated gaming as a way of increasing the amount of data collected through Geo-Wiki. More information about each of these different aspects of Geo-Wiki is provided below.

2.1 Geo-Wiki for Visualisation

Geo-Wiki allows different maps to be visualized via Web Map Services (WMS) on top of Google Earth. For example, the major global land cover maps of the GLC-2000 (Fritz et al., 2003), the 2005 MODIS land cover map (Friedl et al., 2010) and GlobCover 2005 (Bicheron et al., 2008) can be viewed in the online application. Maps showing the spatial disagreement between pairs of land cover maps can also be displayed along with the overall disagreement in the forest and cropland domains. It is also possible to view a hybrid land cover map, created from existing land cover products and crowdsourced data (See et al., 2014b). An example is shown in Figure 1.

<Insert Figure 1>

Other thematic branches of Geo-Wiki allow the user to visualize specific datasets, e.g. biomass.geo-wiki.org contains maps of above ground and forest woody biomass from various sources; these can be visualized and compared (Schepaschenko et al., 2012). Users can also display in-situ forest biomass data for Northern Eurasia where the ultimate goal is to host biomass measurements from other providers around the world. These types of ground-based measurements can be used for the calibration and validation of new biomass products, see e.g. Schepaschenko et al. (2015). Another example is the agriculture.geo-wiki.org branch, which lists all of the cropland maps that we have collected as part of an ‘expertsourcing’ and data sharing workshop (See et al., 2012) in order to create a global hybrid cropland product (see section 3.3 for more information). This global product is now available for viewing, downloading and user feedback at betahybrid.geo-wiki.org (Fritz et al., 2015).

2.2 Geo-Wiki for Crowdsourcing

Geo-Wiki was originally designed in such a way that volunteers could zoom into any place on Earth, see the pixels (or grid squares) associated with the different land cover types (as they are different sizes and therefore overlap in places) and then view what the land cover type is from each of the three global land cover products. Users were then asked to determine what actually appears in those pixels based on what is visible from Google Earth and indicate if each global land cover map characterises the land cover correctly or not. There was also an option to indicate if they were unsure about the quality of a particular land cover product. An example of this original interface is shown in Figure 2.

<Insert Figure 2 here>

However, we soon realized that this provided little incentive to the volunteers to participate so we simplified this approach and ran a series of competitions with prizes. Each competition was driven by a research question or overarching purpose so a sample of pixels relevant to that purpose was first created. For example, in the first competition, the objective was to validate a map of land availability for biofuel production so a sample was randomly selected from this original map. A new branch was developed (humanimpact.geo-wiki.org) and volunteers were randomly taken to these pixels and asked to indicate the land cover type from a simplified legend of ten types along with other information that varied between competitions. Figure 3 shows an example of the interfaces from the first and fifth/sixth competitions while Table 1 outlines the different competitions that we have run to date, the purpose associated with each one, the publications that have resulted, the number of participants per campaign and the average number of points collected per participant. Participants come from a pool of registered Geo-Wiki users which are currently located in 155 countries around the world. Participants are primarily concentrated in Europe, North America and Australia, but countries such as China, India, Brazil, Mexico, Indonesia, Russian Federation, Ukraine, Argentina, Kenya and South Africa fall within the top 25 countries of highest participation. Details of some of the outcomes from these competitions are provided in section 3.

<Insert Figure 3 here><Insert Table 1 here>

2.3 Geo-Wiki for Validation

Geo-Wiki can also be used to create a validation sample if users are interested in validating their own products using Google Earth. Using the ‘Custom area’ option embedded in Geo-Wiki, users can either draw a polygon on Google Earth or import a KML file, which might contain, for example, the boundary of a country or region. Once the area is defined, the user can create a sample at fixed points across the area, e.g. place a validation pixel at every 1 km, or the user can select the total number of points in the sample which are then randomly placed across the area. To undertake the validation, there is a ‘Validate my Custom Area’ button in the main Geo-Wiki interface, where the user is taken to each point in the sample in order to validate it using Google Earth. The user can then download these validations. A new version of Geo-Wiki called LACO-Wiki is currently under construction (Perger et al., 2015). This tool will provide an online facility for users to upload their own maps, create a random or stratified sample, undertake the validation and then calculate the most commonly used validation statistics. At the same time, users will be encouraged to contribute their validations to a global repository, which can then be used for the calibration and validation of other land cover products.

2.4 Geo-Wiki for the Classroom

The ability to use Geo-Wiki to combine remote sensing imagery from Google Earth, digital cartographic tools, *in situ* photography and supporting feature documentation opens up new possibilities for student engagement and inquiry. Traditional laboratory exercises can be transformed into travel adventures that can be readily updated to incorporate, for example, impacts of recent volcanic eruptions or the rate and extent of sea ice decline. As part of a collaboration with the University of Waterloo, we have developed a branch called geography.geo-wiki.org, which has been modified specifically for use in two different undergraduate class assignments (Perger et al., 2014). In a first year physical geography assignment, students were asked to collect pictures of their environment using a mobile phone application (see section 2.5), upload these to Geo-Wiki and to discuss these findings as a social activity within the website. A large number of geo-tagged images were collected and rated by the class as a whole. Many students submitted more than the required postings, and were actively engaged in rating the photography and descriptions posted by others. The majority of the feedback was positive and in many cases was part of what the student liked best about the course. Judging from the effort that students put into the selection of the photos and the descriptions, the exercise proved to be a significant learning experience. A similar assignment was developed for a third year undergraduate class in meteorology in which students were asked to document a weather event that affected their activities on a specific day through the semester. This was held during the fall term of 2012 when Hurricane Sandy and the resulting severe weather produced along the Atlantic Coast of North America provided many interesting examples for discussion.

A second, more interactive type of assignment was then piloted with the students, in which they were asked to identify different processes that are evident from an examination of the Google Earth imagery, or they were provided with photographs of physical features and asked to select the one that best matched the physical process evident for a particular point of interest. For each question, the Geo-Wiki automatically zoomed into the site of interest and the student clicked on one of a series of possible answers. They were also given space to justify their choice and rate the difficulty of the question. Similar positive feedback was received for these different exercises that utilized Geo-Wiki. We plan to continue our collaboration with the University of Waterloo and will improve and evolve these educational resources as we continue to gain more experience in the classroom environment.

2.5 Mobile Applications

The first mobile application to be released was called Geo-Wiki Mobile for the Windows, iPhone and Android operating systems. The idea behind the app was to allow users to take pictures of the landscape and classify the land cover. The geo-referenced pictures, which also have the date, compass direction and tilt recorded, are then uploaded to Geo-Wiki once the user has a wireless connection. An option was built in to allow the user to indicate the offset in metres, particularly in those situations where users take pictures from a road so the corrected coordinate would more correctly reflect the land cover at the actual point and not the point at which the photo was taken. An example of the app is shown in Figure 4.

<Insert Figure 4>

A second version was released, renamed to Pictures Geo-Wiki, with the added feature that users could customize their own legends. For example, if users are interested in crop types or tree species instead of the simple default land cover legend, users simply create the legend in Geo-Wiki itself and then transfer the legend seamlessly to the phone. From these two apps, we have slowly been building up a database of geo-tagged photos, with the idea that they can be used to aid in the validation of land cover along with other sources of geo-tagged photos such as Flickr and Panoramio. Moreover, we now have a branch of Geo-Wiki called Pictures Geo-Wiki, which we hope evolves into a picture sharing site similar to Flickr and Panoramio.

2.6 Geo-Wiki and Game Development

As part of the LandSpotting project funded by the Austrian Agency for the Promotion of Science (FFG), a number of prototype games were developed, where the idea was to see whether gaming could be an incentivising way to gather more data on land cover for Geo-Wiki. After reviewing the gaming landscape and the recent trends in game development, a Landspotting facebook game was developed, which was modelled on the computer game 'Civilisation' but played on Google Earth. As part of building an empire, players were required to paint the landscape with brushes corresponding to different land cover types, thereby providing this information indirectly as part of a broader set of gaming goals. However, players found the game too complicated so a simplified version was created for the iPad. Although there was initial interest and some data were collected and analysed (Sturn et al., 2013), the game did not sustain the players beyond the initial few weeks after the game was launched.

More recently, we have developed a game version of Geo-Wiki called Cropland Capture, which can be played on smart phones, tablets and online (See et al., 2014c). Players are presented with a red rectangle placed on top of satellite imagery. They are then asked to determine if there is any evidence of cropland in the image. They can answer yes, no or maybe (if unsure). For each correct answer, the player receives a single point. For incorrect answers, the players lose one point. Correct answers are determined by majority agreement although players can challenge answers. The game ran for 6 months from mid-November 2013 to May 2014. During that time there were more than 3,000 players who helped us to classify more than 4.5 million images. We are currently analysing the data and will use it to improve our current cropland hybrid product (see section 3.3). A new game will launch in the spring of 2015 using similar game mechanics to search for evidence of deforestation.

3 Results from Selected Geo-Wiki Crowdsourcing Campaigns

The crowdsourcing campaigns run via Geo-Wiki have resulted in a number of different products. Here we provide four different examples of Geo-Wiki derived outputs, and where relevant, further planned developments.

3.1 Mapping Field Size

During the first Human Impact campaign, we gathered information on field size. When the volunteer selected the land cover type ‘Cropland’ or ‘Mosaic of cropland / natural vegetation’, an additional box appeared on Geo-Wiki asking the user to determine and enter the field size using categories ranging from very small to large. Volunteers could click on a link to see examples of how different field sizes appear on Google Earth in order to provide them with some training. These data on field size were then interpolated using a simple inverse distance weighted procedure to produce the first global map of field size (Figure 5). Although there are clearly gaps and interpolation artefacts as a result of the low density of validation points in places, the overall pattern corresponds very well to what we would expect, i.e. large fields with intensive agriculture in the USA, Canada, Europe on one end, and very small fields in Western Africa, parts of China, etc. on the other. More details can be found in Fritz et al. (2015).

<Insert Figure 5>

This product is being further developed in conjunction with segmentation analysis in Google Earth Engine in the framework of the EU-funded SIGMA (Stimulating innovation for Global Monitoring of Agriculture) project. Such a product has value for monitoring purposes, i.e. larger field sizes can be monitored by coarser resolution imagery while small fields need higher resolution. We have plans to run a future Geo-Wiki campaign that is focussed on field size but targeted at specific countries where this information would be most useful from a food security perspective.

3.2 Mapping Wilderness

The third Geo-Wiki campaign was focused on mapping wilderness (Table 1). Using human impact collected from this and all other campaigns, the data were interpolated similarly to field size in order to create the first global crowdsourced map of human impact (Figure 6). Human impact in this context refers to the degree to which the landscape has been modified by humans as visible from satellite imagery on Google Earth and is loosely based on the human modification framework developed by Theobald (2004). As human impact is measured on a continuum, it can also be used to indicate the wildest areas on the Earth. This bottom-up approach to mapping wilderness using the crowd is in sharp contrast to more traditional GIS-based wilderness mapping methods, which integrate proximity-based layers of remoteness and indicators of biophysical naturalness in a top-down manner.

<Insert Figure 6>

3.3 Mapping Hybrid Land Cover

As mentioned above, there are three main global land cover products available, and the development of a hybrid land cover product has always been an important driver in the creation of Geo-Wiki. When the individual global land cover maps are compared spatially, we find evidence of a considerable amount of spatial disagreement between them, but we know that in some places, a particular land cover map is better than another at characterizing the land cover (See and Fritz, 2006). By building a hybrid global land cover map, we are theoretically combining the best characterizations from each one into a single product that is more accurate than the individual products alone. Using crowdsourced data from the Human Impact campaign, we used geographically weighted regression (GWR) to determine the best land cover product at each grid cell. The resulting hybrid land cover map is shown in Figure 7.

<Insert Figure 7>

Performance measures were then used to compare the results of the hybrid product against the individual products using a second, independent crowdsourced validation data set built from Geo-Wiki campaigns 3 and 4 (Table 1). The results showed that the hybrid land cover map outperformed the individual land cover products on the performance measures used (See et al., 2014b). These results serve to demonstrate that GWR and crowdsourced data can be used to improve medium resolution global land cover information with existing products. However, we also recognize areas where the land cover is still not mapped very well so future plans include adding additional land cover maps, e.g. regional and national products, and undertaking further experimentation with the GWR and other data fusion algorithms.

3.4 Mapping Cropland

Three different cropland mapping exercises have been undertaken that have used calibration and validation data generated through Geo-Wiki. The first cropland product was a hybrid cropland map of Africa, which showed the percentage of cropland at a resolution of 1 km. Using five input datasets including different global land cover products and an expert ranking methodology, a cropland probability or synergy map was created. Using FAO (Food and Agriculture Organization) statistics on crop production at the national level and sub-national statistics collected by the International Food Policy Research Institute (IFPRI), the synergy map was then calibrated to produce the final product. The map was validated using data collected through Geo-Wiki using experts (Fritz et al., 2011b).

A second product was created using a similar methodology but at a global level and with a number of modifications such as the integration of many more input data sets including many national products provided to us through a data sharing workshop (See et al., 2012) and the use of crowdsourced data from the human impact campaign to determine the ranking of land cover maps on a country level. This map is available for visualisation, downloading and feedback via the betahybrid.geo-wiki.org branch as shown in Figure 8, and more details can be found in Fritz et al. (2015). This map has been used by IFPRI to create crop type distribution maps using their SPAM methodology. We will continue to improve this hybrid map using the data collected via the Cropland Capture game.

<Insert Figure 8>

More recently, the cropland data collected for Ethiopia through campaigns 5 and 6 (Table 1) were interpolated similarly to the field size and wilderness maps to create a percentage cropland map for Ethiopia (Figure 9). Although a high resolution land use map of Ethiopia exists through AFRICOVER, this map is not currently openly available so one must rely on global land cover maps for this data. A comparison of the interpolated crowdsourced map using standard performance measures showed that this map was better than any of the individual global land cover products for Ethiopia (See et al., 2013b).

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4 Discussion and Conclusions

This paper reports on the latest developments in Geo-Wiki that have occurred since the first two papers appeared outlining the basic concept behind the tool (Fritz et al., 2009, 2012). Since then a number of successful crowdsourcing campaigns have been carried out, where a selection of the results from these data collection efforts have been reported here. Other key developments have been an expansion in the number of Geo-Wiki branches available, and the release of mobile applications and games to engage a wider audience in land cover validation. Although Geo-Wiki was originally designed as a land cover validation tool for correcting global land cover maps, this still remains the overarching objective. Yet it has become clear that there are many other applications that can benefit from Geo-Wiki technology. Geo-Wiki as an interactive teaching tool has real potential for use in modules on remote sensing, physical geography and any discipline that uses georeferenced data. Gaming remains an attractive and incentivizing way of engaging a different audience in land cover validation as well as raising awareness about the environment. Mobile phones and tablets are becoming one of life's necessities, bringing increasingly more functions into a single device. One day mobile devices may even replace laptops as these tools evolve into wearable devices (EVRYTHNG, 2014). As this happens, everyone becomes a potential citizen sensor. New 3D mapping devices that fit onto smart phones, e.g. the Structure Sensor produced by Occipital, may one day be integrated directly into mobile or wearable devices, which will open up new possibilities in mapping vegetation and urban form using crowdsourcing.

What the examples in section 3 serve to illustrate is how easy and cost-effective it is to create maps using crowdsourced information, particularly in those situations where such maps do not exist or where they can be used to correct existing maps in a hybrid or data fusion approach. OpenStreetMap is another good example of successful bottom-up mapping. The data produced are much richer than the authoritative data that would be collected by mapping agencies, as many other types of information are collected according to the interests of the citizen mappers. However, the data collection is not as spatially comprehensive as authoritative data since citizens choose where, what and when they want to map. Mapping agencies have been slow to recognize the potential of VGI for updating information faster than they would normally have the capacity or budget to do but they cannot ignore these initiatives for much longer. What remains the principle obstacle is concerns about data quality. Although papers are beginning to address this topic with respect to VGI (Goodchild and Li, 2012; Haklay, 2010; Haklay et al., 2010), there are still no concrete methods for implementing VGI data conflation with authoritative data that utilize automated methods of filtering or utilize information about the quality of individual contributors. Some papers suggest that VGI quality is not currently sufficient for this purpose, e.g. (Fairbairn and Al-Bakri, 2013), while others recognize the need for experts to be involved in the training and quality control (Jackson et al., 2013). For Geo-Wiki this is also an area of concern. We use a set of controls or images where the answers are known in order to judge the quality of the contributions. Some initial work has shown that the crowd are able to interpret satellite imagery to a reasonable accuracy but that some land cover classes are harder to interpret than others, which requires additional training (See et al., 2013a). We are currently experimenting with the development of an index of quality, which will be built for each contributor and change over time as volunteers improve. We will use this information in any applications that incorporate crowdsourced data in further scientific research.

In addition to making improvements in the way data quality is handled in Geo-Wiki, there are a number of new branches being further developed in the short to medium-term. For example, there is a Cities branch of Geo-Wiki that is supporting the World Urban Database and Access Portal Tools (WUDAPT) initiative (Ching et al., 2014). Geo-Wiki is being used to capture urban morphology for climate modelling purposes but the data have many other potential applications, e.g. energy assessment, greenhouse gas estimates and urban planning. A mobile application for the collection of other climate-relevant variables such as building materials and building heights is also planned for development in the future.

A Geo-Wiki branch has been developed for the display and query of information about livestock. Funded by the International Livestock Research Institute (ILRI), this application will move Geo-Wiki into much more of a visualisation and scenario generation tool. Users will be able to view the current status of livestock numbers by national and subnational zone (where available) as well as the emissions generated by the mix of livestock in a particular place. Through the scenario generation tools that are being built into this application, it will be possible to see the effect of changes in emissions if the livestock mix is altered. The application is intended as a decision support tool but will also be used to gather and display information about livestock on the ground that has been collected via a mobile application.

A recent project with Zurich insurance on flood risk will involve the development of a risk Geo-Wiki application supported by a mobile app. The site will primarily be used as a flood risk visualisation tool for the case studies that are currently under consideration while the mobile app will be used to collect data on the ground and help communities and NGOs in decision making through tools such as cost-benefit analysis and multi-criteria evaluation.

In addition to new branches, further developments will continue to take place on the core Geo-Wiki product. Social networking tools are in the process of being added, which will allow users to interact with one another during campaigns. We are looking to continually enhance the user experience and make land cover validation a fun and worthwhile endeavour.

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Table 1: List of Geo-Wiki campaigns

Number	Competition	Purpose of the Competition	Number of participants and average contribution
1	Human Impact	To validate a map of land availability for biofuel production (Fritz et al., 2013)	65 participants 819 points/ participant
2	Hotspots of Map Disagreement	To collect validation points in the areas were the GLC-2000, MODIS and GlobCover disagree with one another (See et al., 2014b)	61 participants 498 points/participant
3	Wilderness	To collect land cover and human impact in order to determine the amount of global wilderness (See et al., 2014a). The locations used were the same as that of a Chinese 30 m global land cover map (Gong et al., 2013)	65 participants 506 points/ participant
4	Global Validation Dataset	To collect data at the same locations as the validation data assembled for the Chinese 30 m global land cover map (Zhao et al., 2014)	26 participants 1363 points/ participant
5 & 6	Hackathon and IIASA Competition	To collect data on the degree of cultivation and the degree of human settlement in Ethiopia in the context of land grabbing (Albrecht et al., 2013; See et al., 2013b)	36 participants 2278 points/ participant

Figures

Figure 1: Visualisation of spatial disagreement on Geo-Wiki

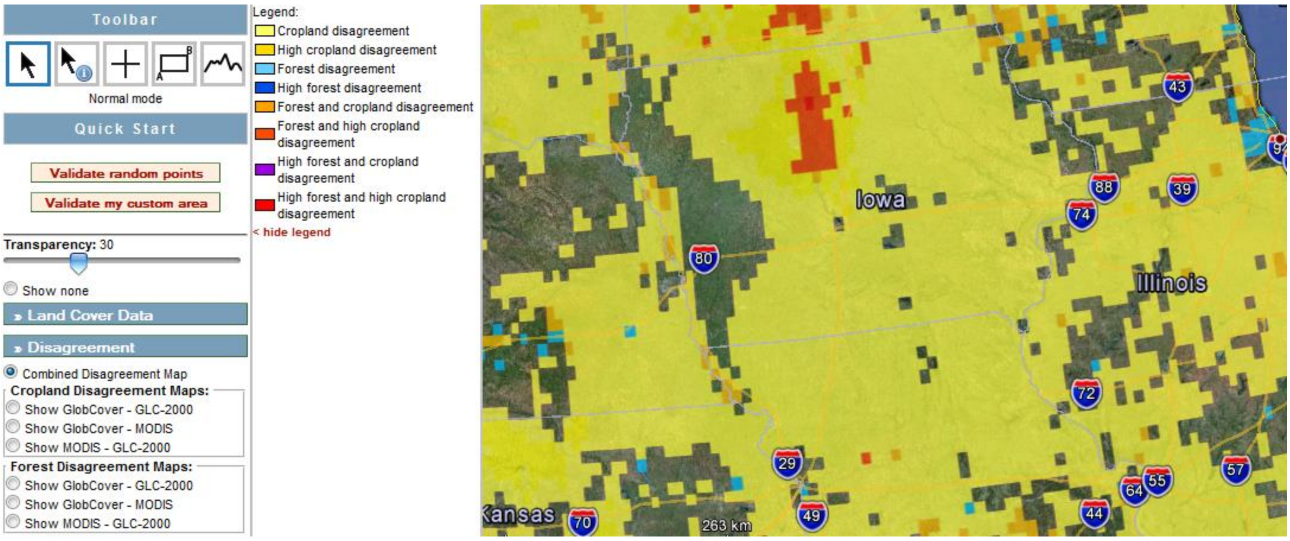

Figure 2: Validation of global land cover maps in the original Geo-Wiki

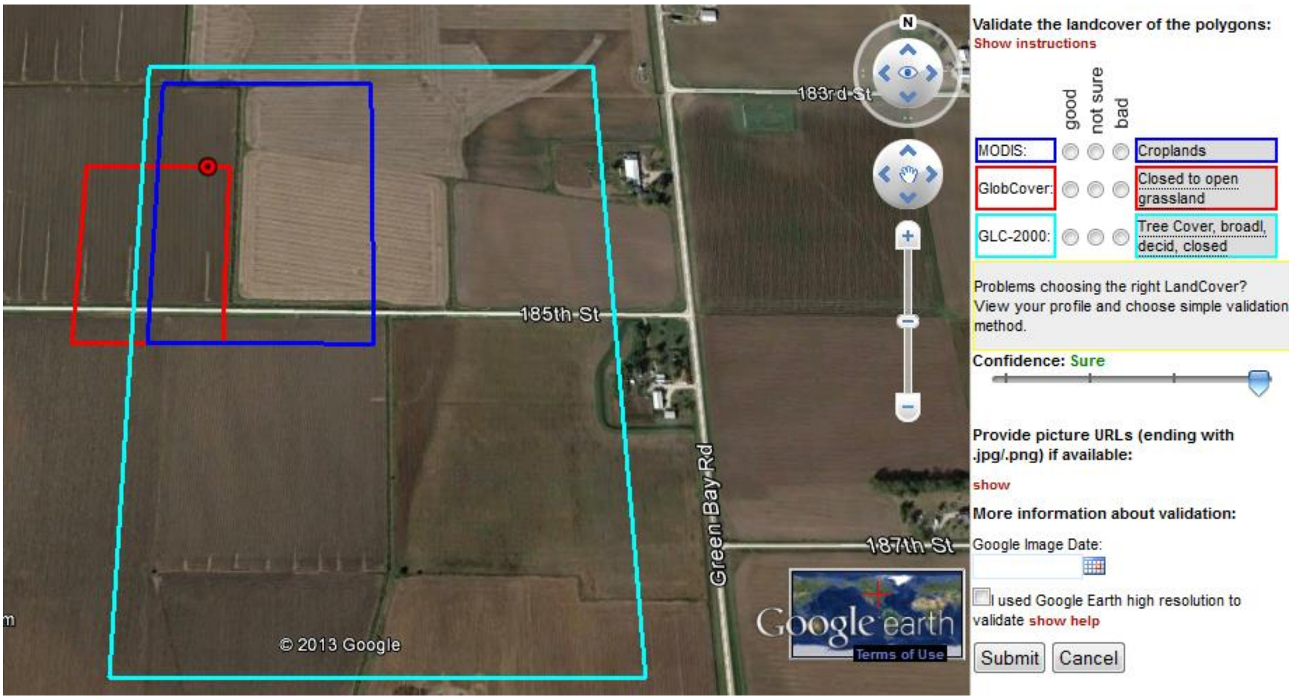

Figure 3: Examples of the Geo-Wiki interface in a) campaign 1 on Human Impact and b) campaign 5 on the Hackathon

(a)

(b)

Figure 4: The Pictures Geo-Wiki mobile app on the left with the uploaded pictures shown on Geo-Wiki on the right

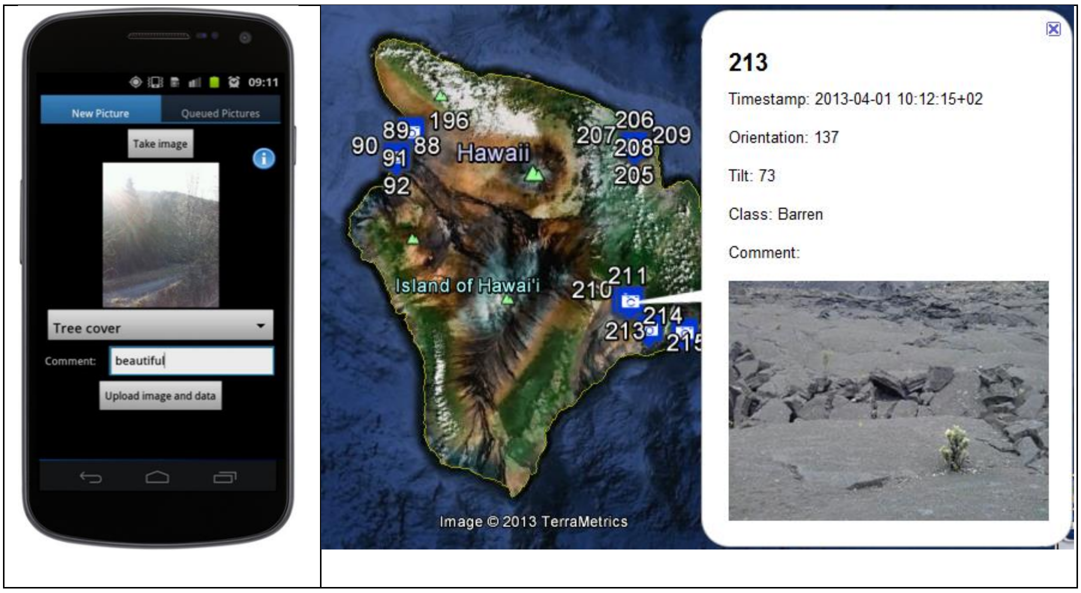

Figure 5: A crowdsourced map of agricultural field size produced from data collected during the first Geo-Wiki campaign

<see uploaded tiff>

Figure 6: A crowdsourced map of human impact produced from data collected from four Geo-Wiki campaigns

<see uploaded tiff>

Figure 7: A hybrid global land cover map produced via geographically weighted regression of crowdsourced data and the three main global land cover maps: GLC-2000, MODIS and GlobCover

<see uploaded tiff>

Figure 8: The global hybrid cropland map available for visualisation and online feedback on betahybrid.geo-wiki.org

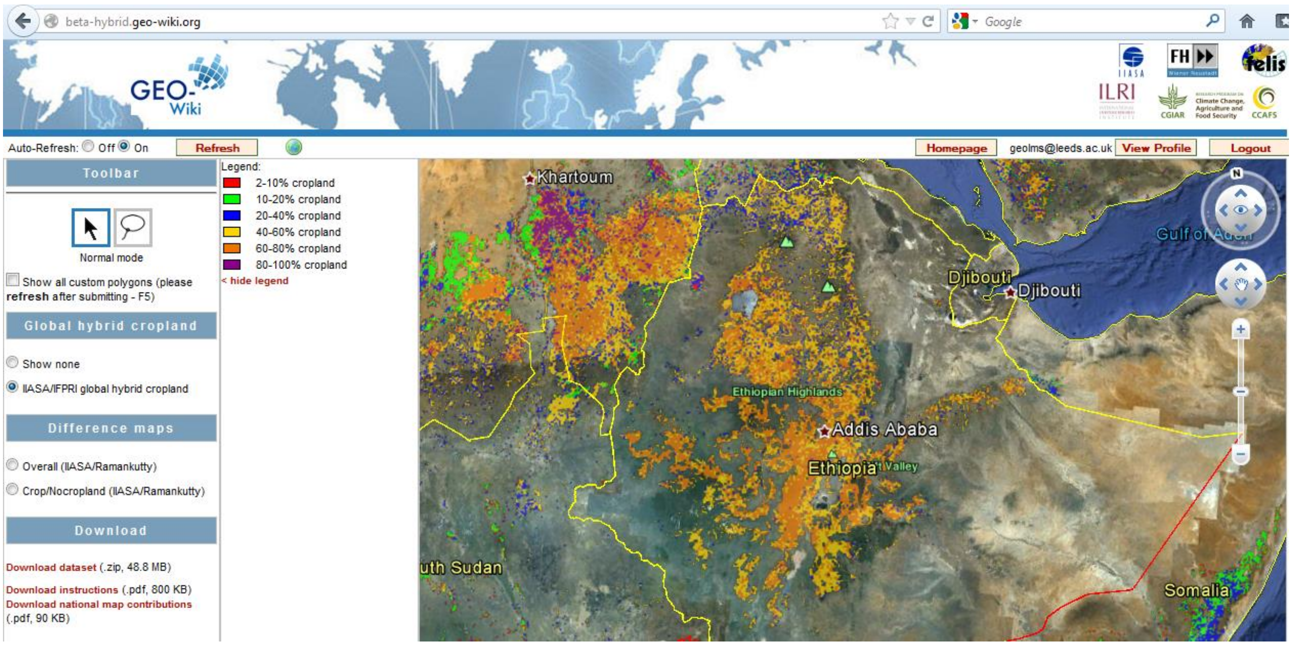

Figure 9: The map of Ethiopian cropland created from crowdsourced data collected through Geo-Wiki campaigns 5 and 6