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Advancing terrestrial conservation through remote sensing

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ABSTRACT

Conservationists recognise that remote sensing can make a substantial contribution to their effort to monitor the environment to better understand and reduce the impact of anthropogenic activities. However, often it is perceived that the needs of the terrestrial conservation community are not being met by the remote sensing community. The first step to bridging this gap is the improved communication between both communities, and the compilation of a list of needs and best practises for conservation applications. Here we review five recent workshops that help to answer the broad question "What conservationists need and want from remote sensing". We identify recurring requests, and consider potential ways forward for the conservation and remote sensing communities to start to deliver data or tools to address these needs.

1. Introduction

Conservation relies upon monitoring data to identify priorities, set targets and track the effectiveness of actions. Timely delivery of monitoring information is essential since the sooner conservation challenges are identified, the sooner solutions can be developed and implemented. Monitoring has generally used data collected in situ, but these field data, even if of irreplaceable value, can be expensive and even difficult to collect in remote areas and rely upon either a large number of paid staff or skilled volunteers. Furthermore, many biodiversity datasets are not evenly distributed around the globe, or even within ecologically important areas such as the Amazon (Pitman et al., 2011). A lack of monitoring can be attributed to a variety of factors. These include a lack of resources (McCarthy et al., 2012), particularly in certain biodiversity-rich developing countries and insufficient infrastructure in remote areas.

The potential of satellite remote sensing to contribute to conservation monitoring and broader biodiversity research has been recognised for some years (e.g. Kerr and Ostrovsky, 2003; Turner et al., 2003). Conservation and biodiversity are major users of remote sensing data (Turner et al., 2015). However, the conservation community itself has articulated that they are not taking full advantage of the potential of remote sensing data. In various fora over recent years this community has also noted that the remote sensing community could improve its understanding of the actual needs of the conservation community, rather than concentrating on the development of methods and products that, whilst highly advanced and novel, do not meet the perceived basic needs of the conservationists. A number of workshops and surveys have been convened in recent years in an attempt to identify the major needs of the conservation community, and improve communication between them and the remote sensing community. Here, we present a synthesis of five such workshops and surveys in order to highlight recurring themes for terrestrial monitoring and paths forward. This synthesis should direct the remote sensing community towards the topics that are priorities for terrestrial conservation and identify next steps to make better use of remote sensing data for conservation and biodiversity science. It should also be seen as a prompt to the conservation community to make better use of the remote sensing data already available. Finally, it could act as a marker against which progress to meeting these needs can be measured.

We draw information from Green et al. (2011), who described user needs from a series of workshops in 2009 and 2010, held in conservation organisations (all of which had an international programme, and some of which work almost entirely outside the UK) in and around Cambridge, UK. The needs identified by these workshops were assimilated, allowing broad topics for a workshop attended by conservationists and remote sensing experts held in Cambridge in April 2010. We also consider a facilitated discussion on data access and usage at the International Congress for Conservation Biology in Auckland, New

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Zealand in 2011, led by NASA and Conservation International. Next, in October 2012 a Committee on Earth Observation Satellites (CEOS) — Biodiversity workshop was convened at the German Aerospace Center (DLR-DFD). This event was informed by responses from a questionnaire on needs and uses of remote sensing data (Leidner et al., 2012). In January 2013, The Wildlife Conservation Society (WCS) ran a NASA funded workshop that brought together 30 remote sensing experts and conservation practitioners to specifically identify the top ten important questions in conservation that could be addressed using remote sensing. This was informed by needs submissions from a wider pool of conservationists and remote sensing scientists (Rose et al., 2014). Finally, a workshop in October 2013 at the European Commission's Joint Research Centre (JRC) discussed the use of remote sensing for conservation management, with a particular focus on developing countries (Leidner et al., 2013). This was again informed by a pre-workshop questionnaire which directed focus on providing remote sensing operational support for local to global levels of conservation decision making.

The multiple assessments from overlapping but distinct conservation and biodiversity research communities discussed a wide range of topics and produced summaries of needs for remote sensing in conservation. While some needs were quite specialised (e.g. identifying artesian wells — Green et al., 2011), others were much broader, such as a tool for identifying rapid changes in land cover in near real time (Rose et al., 2014). There were recurring themes throughout the five workshops that enabled us to group these requirements into three major topics that we feel represent pressing remote sensing issues within the terrestrial conservation community. In addition to these topics, the importance of open access to free data was regularly highlighted. Two major programmes from NASA /USGS and ESA (Landsat 8 and Sentinel respectively) will make higher spatial (20–30 m) and temporal resolution data available for free; something that has been rightly welcomed by the conservation community (Turner et al., 2015), and because of the recent attention given to this topic (e.g Turner et al, 2013; Turner et al., 2015), we do not consider it further here.

2. Terrestrial habitat extent and change

Conservationists are in need of current information on habitat extent and change in extent. An associated need is for information on the distribution of species and changes in these distributions. Remote sensing data have already been widely used for mapping potential habitat and land cover for over 25 years (e.g. review by Gottschalk et al., 2005). The conservation community has utilized coarse resolution global land cover maps such as GLC2000 (Bartholomé and Belward, 2005), and have also leveraged the availability of national land cover maps (where they exist). However, the conservation communities surveyed felt that the spatial resolution was too coarse and that they do not always have an appropriate thematic resolution (i.e. do not separate land cover types of importance). They also indicated that their accuracy needed to be improved (Leidner et al., 2012, Rose et al., 2014). Subsequent to the needs assessments, Hansen et al. (2013), produced a global forest change product. While this will prove useful, it is still limited to one broad land cover type. Wetlands, grasslands, and other habitats are of critical interest to the conservation community, and consequently there remains a need for maps and change assessments with these land cover categories at sufficient spatial resolution. Developing and standardizing tools that would empower conservationists to produce their own land cover change assessments rapidly would go a long way to meeting this need. This can be achieved using Open Source software with some training (Wegmann et al., 2015). Near real time alerts of rapid changes in land cover, indicating rapid conversion, were also a recurring need from the conservation community. Such systems are under development (e.g. Global Forest Watch — http://www.globalforestwatch.org/). Until appropriate systems are available the conservation community could make better use of existing data that might indicate some, if not all, rapid changes in land cover. The thermal anomaly maps of fires (https://firms.modaps.eosdis.nasa.gov/firemap/) has already been used to good effect (e.g. Palumbo, 2013). These data, while not detecting every burning event, could be used to indicate unusual burning patterns which might be associated with land cover change. Near real time monitoring of vegetation phenology and similar is available for Africa (http://estation.jrc.ec.europa.eu/index_en.htm), and while not capable of identifying changes in land cover, it can provide some indication of potential vegetation stress in a yearly and long term cycle. This group is currently producing a tool for assessing land cover change using medium-high resolution satellite data in broad vegetation types at individual protected areas (Simonetti et al in prep, Szantoi et al in prep). This IMPACT tool would meet a major need of the conservation community — simple tracking land cover change on sites of conservation importance.

Improved assessments of land cover and land cover change from remote sensing would contribute directly to another recurring need — data for the assessment of the effectiveness of conservation interventions. Assessment of interventions and actions will allow conservationists to identify helpful actions and diagnose unproductive ones in order to inform financially efficient ways to produce successful outcomes through adaptive management (Ferraro and Pattanayak, 2006). This need operates across multiple spatial scales, ranging from the use of remote sensing to assess the effectiveness of individual protected areas through to tracking progress towards international treaties. Perhaps such application is among the most abundantly used ones concerning applying remote sensing for conservation, with a number of studies now concluding protection is effective at reducing (but not halting) land cover change on protected areas (e.g. Andam et al., 2008 for forests, Beresford et al., 2013 for all land cover types). Subsidised management of farmland through agri-environment schemes is widespread in many countries. However, monitoring compliance can be difficult due to the scale of areas involved. Again, remote sensing has been utilised to track the extent to which schemes are being implemented as required, allowing the effectiveness of the schemes to be assessed (Carey et al., 2003). At the global scale, the potential role of remote sensing for measuring Essential Biological Variables (EBVs) to monitor progress to the 2020 Aichi targets has been noted (Pereira et al., 2013).

The increasing availability of data and products that examine land cover changes will meet these needs, but only if the tools to deliver land cover change assessments are operationalised and temporally and spatially comparable. The availability of tools and data to meet these needs is increasing (see above), but the conservation community needs to utilise them, and accept their limitations. However, these tools and data do now mean assessments of land cover change on sites and in species ranges can be more easily made, allowing assessment of the effectiveness of terrestrial conservation. Continued development of such tools by the remote sensing community would be most effective when informed by feedback from users (ie the conservation community), necessitating a good ongoing dialogue between the communities.

3. Mapping terrestrial ecosystem services

Another recurring topic was the use of remote sensing to measure ecosystem services. Potentially, due to its topical nature, many of the discussions focussed around the impacts of and mitigation for changes in the environment from climate change. Consequently, the recurring needs might present a biassed view of the contribution that remote sensing can make to mapping ecosystem services, but these were the topics that came out across the multiple workshops. Remote sensing data are already a major tool in measuring forest carbon stocks for REDD (GOFC-GOLD, 2008). The conservation community is reasonably well aware of the applications of remote sensing for this topic, but is perhaps less well aware of the potential for monitoring and quantifying other ecosystem services. These include monitoring water bodies (Haas et al., 2009) and the availability of fuel wood (highlighted by Arroyo