Forest Watcher: Employingcitizen science in forest management of Nepal

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Abstract

Nepal's deforestation rate is one of the highest in the world, at 25 percent over the past 20 years. In Nepal, community forest user groups (CFUGs) take care of natural resources and promote social inclusion. The success of a conservation program depends on the involvement oflocal people.

Forest Watcher is a mobile application that helps collect critical baseline data about forest status and strengthens community participation in forest conservation. It provides dynamic online forestmonitoring and alert systems. Data can be stored in the mobile device when it is not connected to the internet. Hence, regardless of connectivity, frontline forest guardians and citizen scientists can quickly access Global Forest Watch (GFW) satellite-derived forest datasets to collect near- real-time tree cover loss, deforestation and fire alerts information in the field.

In collaboration with the relevant Divisional Forest Offices and Local Councils, we trained 68 elected CFUG members from 34 community forests across seven districts of western Nepal to use Forest Watcher. In total, 6,657 hectares of community forest were monitored and 2,983Global Land Analysis and Discovery (GLAD) deforestation alerts were reported from March

2020 to December 2020. CO2 emissions were the highest in Jumla as the district experiencedthe greatest tree cover loss (1,160 ha from 2001 to 2020). With Forest Watcher, even during the COVID-19 pandemic, local communities were able to patrol the forests at a safe distance and receive alerts at their fingertips. With mobile applications, data collection will become more efficient and accurate and delivered in real time, thereby reducing the risk of error. It will also bepossible to authenticate data. Such data will facilitate the development of long-term effective conservation plans for forests and boost current conservation efforts.

Keywords: *Forest Watcher, Community Forest, Forest Guardians*

Introduction and background

Indigenous peoples and local communitiesare the forefront stewards of natural resources. Forests are best protected when local people have rights over their management (Petersen and Pintea 2017).

Their traditional knowledge complements scientific research and helps support conservation strategies, especially in remotemountain ecosystems where significant

data gaps still exist. In the Rio Declaration on Environment and Development (United Nations 1992), the United Nations GeneralAssembly proclaims that "environmental

issues are best handled with the participationof all concerned citizens" (Principle 10).

According to GFW, Nepal lost 47,100 ha (47.1 kha) of tree cover between 2002 and 2020, including 3,800 ha (3.8 kha) of humid primary forest.[1] A number of factors are contributingto deforestation and forest degradation in Nepal, including habitat degradation, illegal harvesting, wildfires, agricultural expansion, and weak state control over the land (Chaudhary et al. 2016). Nepal's deforestation rate is one of the highest in the world, at 25 percent over the past 20 years. To combat growing issues of deforestation and forest degradation, Nepal's government has adopteda strategy centered on the 1976 National Forestry Plan, which promotes community participation in sustainable forest management and conservation (Springate-Baginski et al.

2003). In least developed countries like Nepal,the community-based forest management (CBFM) approach has so far been one of the most promising achievements in the green economy sector. Nepal continues to be a global leader in CBFM development (Ojha et al. 2007; Pathak et al. 2017). The approach hasdemonstrated success in its dual objectives

of ecological restoration and sustainable livelihood enhancement. Under the CBFM framework, 1.8 million hectares of forest land has been handed over to 19,361 CFUGs, representing nearly 1.45 million households, or35 percent of Nepal's population (DoF 2015). Some research has shown that conservation efforts without community participation

often collapse, particularly in areas with high population density, resource sharing disputes, and highly fragile and smaller protected areas (Isager et al. 2001; Brofeldt et al. 2014).

Recent technological breakthroughs in remote sensing have allowed a qualitative leap in

our understanding of forest ecosystems and management (Goetz and Dubayah 2011; Henry et al. 2015; Abad-Segura et al. 2020;

FAO 2020). Remote sensing observation is emerging as an indispensable tool for tracking land cover changes and is gaining

significant momentum in different aspects of applied ecology and conservation biology (Wang et al. 2010; Kumar 2011; Nagendra et al. 2013; Lawley et al. 2016). Conventional forest assessment methodologies include extensive field surveys, paper-based data

collection and block/transect-based2 analysis of forest stocks. Forest guardians (FGs) used to record data manually on datasheets, which resulted in a lot of errors. In addition, these conventional forest monitoring practices can limit the timely and precise analysis of survey data. Mobile applications have immediate benefits over conventional paper-based approaches: they allow FGs to record data much more easily and on site.

Description of the innovation

Study area

Within a latitudinal range of approximately 200 km, Nepal undergoes vast altitudinal changes, ranging from 60 m along the southern border up to 8,848m on Mount Everest in the north. This difference greatly impacts Nepal's landscape and climate. The study area, illustrated in Figure 1, includes seven districts – Kalikot, Jumla, Jajarkot, Rolpa, Dolpa, Rukum West and Rukum East – situated in Western Nepal, and covers 18,644 km2, including 6,079 km2 of forests. This area connects three protected areas (PAs), namely: Rara National Park, Dhorpatan Hunting

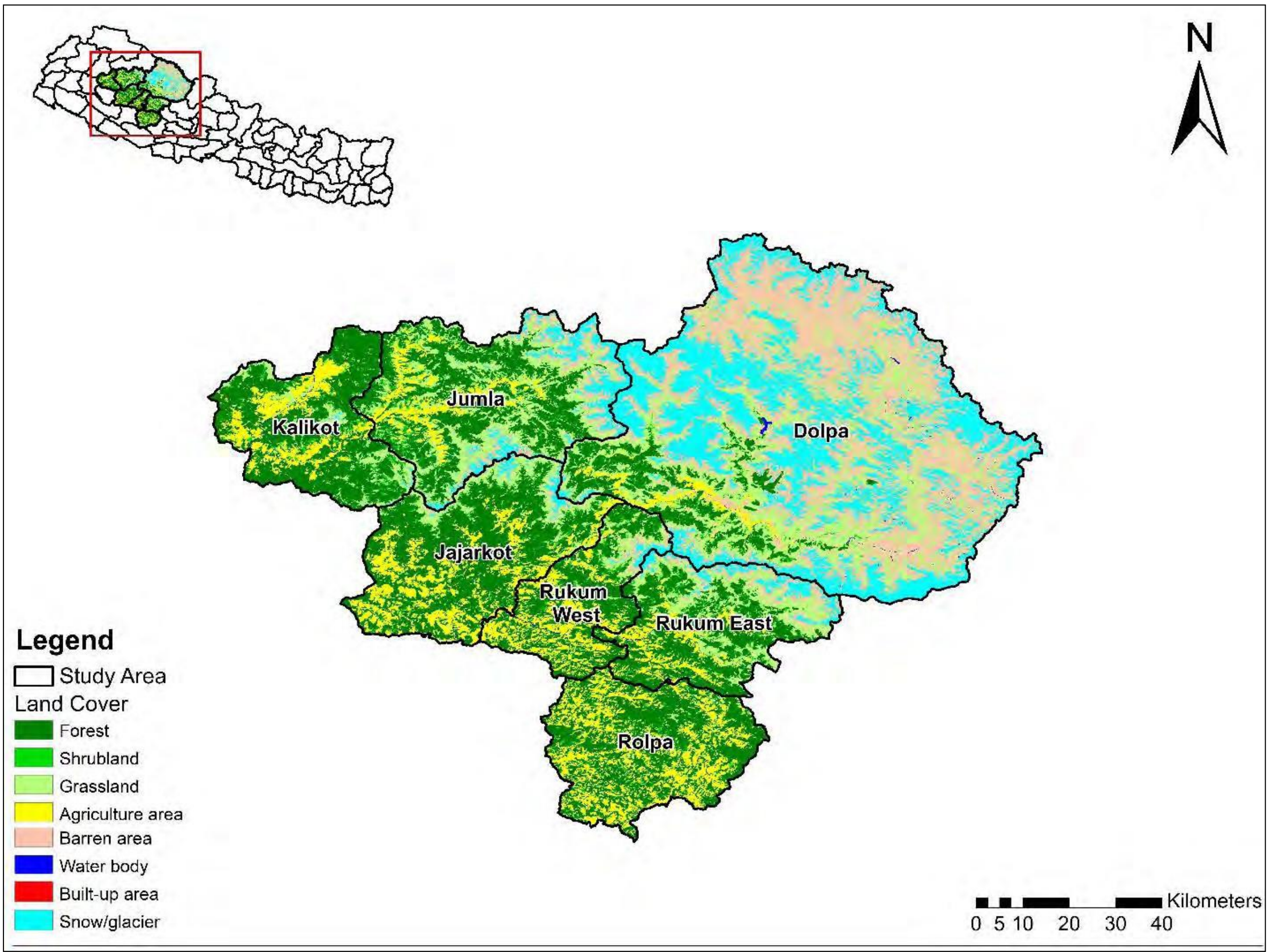

Figure 1: Study Area. Land Cover data taken from ICIMOD (2010).

Reserve, and Shey Phoksundo National Park. The study area mainly comprises Himalayan subtropical pine forests, subalpine conifer forests, broadleaf forests, alpine shrubs and meadows. Intact forests can be found only in Jumla and Jajarkot districts. Some areas have warm and temperate climate with dry winters and warm summers, whilst others have a polar tundra and snowy climate with dry winters and cool summers. The Kalikot district is the westernmost distribution edge (81.66° E) for some of the world's most endangered animals like the Himalayan Red Panda.

From 2001 to 2020, tree cover loss in the seven districts of the study area amounted to 4.63 kha.3 Over the 20-year period, there were substantial variations in tree cover loss, including a steep surge in 2017 (Figure 2a).

Figure 2b illustrates tree cover loss at the district level between 2001 and 2020. The greatest tree cover loss occurred in Jumla (1.12kha),4followed by Kalikot (912 ha),5 Jajarkot (785 ha),6 Rukum East (537 ha),7 Dolpa (481 ha),8 Rukum West (423 ha)9 and Rolpa (375 ha).10

From 2001 to 2020, tree cover loss in the study area released 2.74 million metric tons (Mt) of CO2e i.e. 2.09 Mt of CO2 and 0.65 Mt of other greenhouse gases (GHGs), into

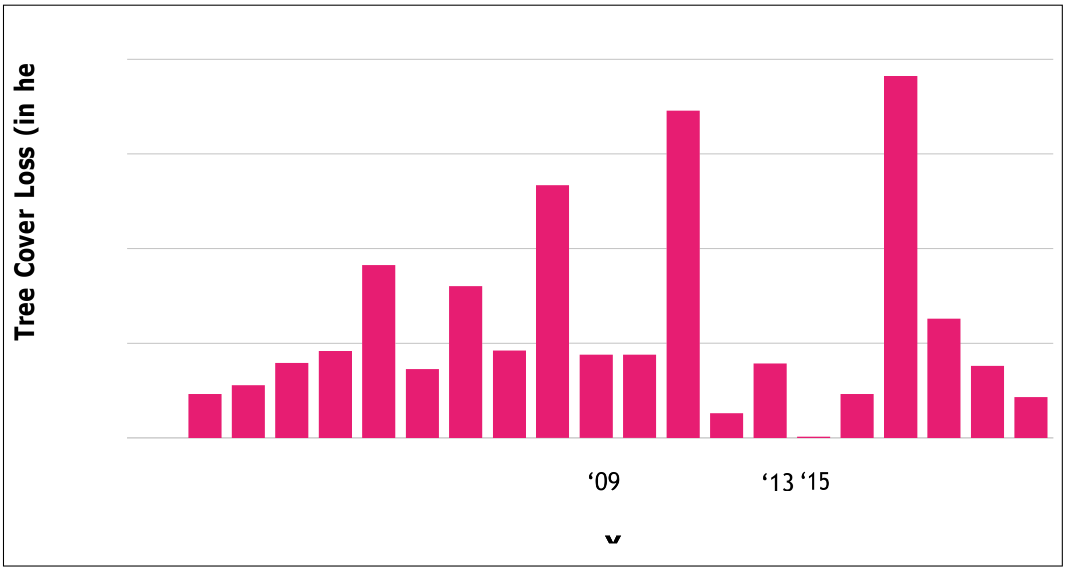

Figure 2a. Total tree cover loss in the study area from 2001 to 2020 (>30% tree canopy:these estimates of natural forest loss do not take tree cover gains from reforestation and afforestation into account).

Source: GFW (2021)[11]

the atmosphere 12 (Figure 3). Over the same period, at the district level, GHGs emissions were highest in Jumla (660 kilotons (kt) of CO_2e, including 502 kt of CO_2 and 158 kt

of other GHGs), followed by Kalikot (562 kt of CO_2e; 422 kt of CO_2 and 140 kt of other GHGs), Jajarkot (448 kt of CO_2e; 344 kt of CO_2 and 104 kt of other GHGs), Rukum East (336 kt of CO_2e; 247 kt of CO_2 and 89 kt of other GHGs), Rukum West (274 kt of CO_2e; 205 kt of CO_2 and 69 kt of other GHGs),

Dolpa (245 kt of CO_2e; 184 kt of CO_2 and 61 kt of other GHGs) and Rolpa (214 kt of CO_2e; 168 kt of CO_2 and 46 kt of other GHGs).

Even though Nepal is among the smallest contributors to GHG emissions, it is ranked among the world's 10 most vulnerable countries to the impacts of climate change because of its high poverty rate and low adaptive capacity (INDC 2016). Temperatures

in western Nepal have increased by an average of 1.2°C over the last 36 years (1975– 2010). This is also reflected in the climate change vulnerability index:13 this ranking index refers to how vulnerable a system is to the negative impacts of climate change, such as climate variability and extremes, as well as how well it can deal with them (Houghton et al. 2001). The climate change vulnerability index for Dolpa, Kalikot and Jajarkot districts ranges from 0.601 to 1.00, which is very high in comparison to other districts in the study area and in the Karnali province, the largest province of Nepal (MoFSC 2016).

Due to unsustainable harvesting practices and infrastructural development, forest fires are one of the major causes of deforestation in Nepal (Chaudhary et al. 2001). In Nepal, forest fire events have increased over the years. Warm winters and prolonged droughts have triggered wildfires, burning thousands of hectares of forest and wildlife habitats inside and outside protected areas. There were

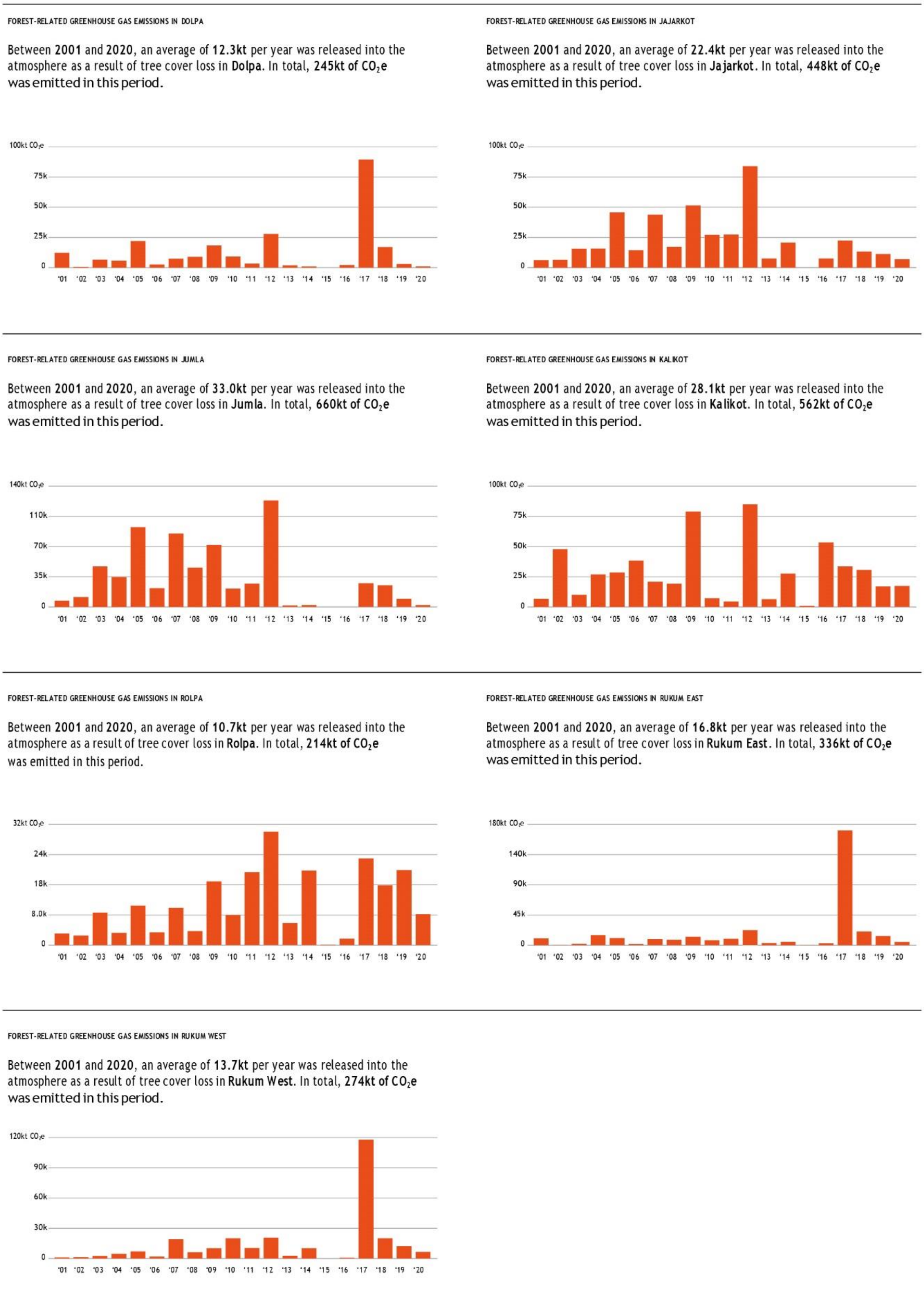

Figure 2b. Tree cover loss by district, from 2001 to 2020 (>30% tree canopy: these estimates of naturalforest loss do not take tree cover gains from reforestation and afforestation into account)

Source: GFW (2021)[4-10]

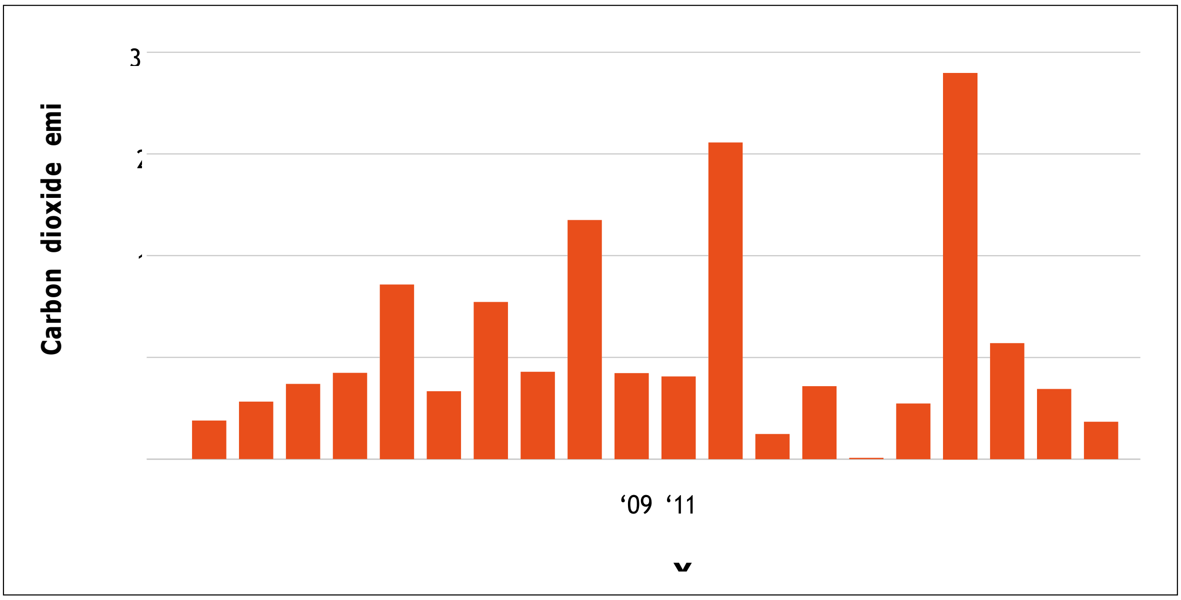

Figure 3. Total CO_2 emissions from biomass loss in the study area

Source: GFW (2021)[14]

35,374 wildfires reported between 2000 and2016 via MODIS [15] satellite images, with a burnt area of 1,723,920 hectares (Bhujel et al.2017). Wildfires are also frequent in the study area. Between 2003 and 2013, the number of annual active fire days in the study area varied from 1 to 24 days, with Jajarkot district experiencing the most fire days, ranging from15 to 24 (Matin et al. 2017). Data on active

fire days was collected from the Moderate Resolution Imaging Spectrometer (MODIS) on NASA’s Terra and Aqua satellites; this dataidentifies the location of the fire. The majorityof the fire cases in the study area were reported in April, November, and December.

Selection of citizen scientists

The involvement of local communities iscrucial for the success of a conservation

program. Since local people know their forests and wildlife best, involving them directly from the onset can build a sense of ownership and ensure active participation inthe program (Williams et al. 2011). Community-based monitoring programs can raise

local awareness on the long-term value of sustainably managed forests and on the aesthetic value of natural ecosystems.

Through citizen science programs, local actors can strengthen their capacity to usestructured, scientific techniques to assess habitat quality and conservation threats.

Science-based monitoring techniques can empower local forest users by not only educating them about conservation and sustainable management of forests but also motivating them to engage in initiatives to protect endangered species. For instance, in western Nepal, a community-based monitoring program has helped to combat illegal poaching of endangered species, likethe Himalayan red panda, by locating and dismantling traps and snares.

In the study area, two people were selectedfrom each CFUG to act as citizen scientists based on their knowledge of the local topography, flora and fauna and literacy to handle data sheets and equipment (e.g.

smartphone, GPS, Vernier caliper[16]). CFUGsgave priority to livestock herders and ex- poachers meeting these criteria.

GFW platform

Global Forest Watch (GFW)[17] is an open- source platform providing real-time spatial data collected through remote-sensing technologies, as well as tools and technologyto better monitor and analyze forest changes across the world (Zhang et al. 2020). This platform, launched by the World Resources Institute (WRI) in 2014, is a free forum facilitating community involvement in forest cover monitoring (Hansen et al. 2016). It offersusers the possibility to create customized datasets focusing on their own areas of interest. Globally, GFW allows the monitoring of over 50 million hectares of forest (Zhang

et al. 2020), and more than 2 million people,

including researchers, conservationists, law enforcement officials, and local and indigenous communities are now using this

platform to assess forest cover changes (Renet al. 2015; Allan et al. 2017; Curtis et al. 2018;Yang et al. 2019). This innovative technology has empowered local communities to bettermonitor their forests despite their limited resources.

GFW datasets typically include information on:

forest changes: deforestation alerts, fire alerts and tree cover changes at differentresolutions, frequencies, and scales;

land cover: data on tree cover, tree heightand tree plantations, including coverage and distribution of different forest

types, such as intact forest landscapes,mangroves, or primary forests;

land use: legally protected areas, areas collectively held by indigenous people and local communities, as well as areas allocated by the government for differentcommodities and infrastructure;

carbon stocks: potential carbon sequestration rate, carbon emissions rate, and carbon density values in topsoil and aboveground living woody biomass in different forest types, including mangroves;

biodiversity: localization of biodiversity hotspots and critical conservation sites harboring different endangered species,effects of forest changes on global biodiversity intactness[18].

GFW builds upon coarse spatial and hightemporal resolution datasets such as:

Global Land Analysis & Discovery (GLAD)

The Global Land Analysis and Discovery (GLAD) laboratory[19] at the University of Maryland monitors land use changes aroundthe world and assesses their causes and impacts. This dataset is the first Landsat- based alert system for tree cover loss produced by the University of Maryland, assisted by GFW. These GLAD alerts have

a 30 m resolution, compared to 250 m for MODIS imagery. Therefore, they can track tree cover loss much more precisely. GLAD alerts particularly cover land areas between 30° north and 30° south (Hansen et al. 2016).

Visible Infrared Imaging Radiometer Suite (VIIRS)

The Visible Infrared Imaging Radiometer Suite (VIIRS),[20] aboard the NOAA/NASA Suomi National Polar-orbiting Partnership (SNPP) weather satellite, is the most recent fire tracking tool used by FIRMS[21] to track fire incidents around the world in near real time. VIIRS sensors collect the information and analyze it with a fire detection algorithm to mark active fires. The VIIRS dataset has substituted the previous MODIS active fires dataset of GFW. Its higher spatial resolution of 375 m, instead of 1 km, and improved night-time performance allows the detectionof smaller fires (even at night) and a more accurate delimitation of fire perimeters[22].

Under good atmospheric conditions, such systems have fair coverage and provide near-real-time data to many monitoring applications. The main drawback of such sensors is their coarse spatial resolution, which is nonetheless sufficient for many landuse applications.

Forest Watcher mobile application

In partnership with Google, the Jane GoodallInstitute and the National Forestry Authority in Uganda, WRI has launched a free open- source software called Forest Watcher, available via both the Apple App Store and Google Play Store[23] (WRI 2019). Data can bestored in the mobile device when it is not

connected to the internet. The Forest Watchermobile application makes satellite-derived alert systems and different spatial datasets from GFW available offline, including in the field. Regardless of internet connectivity, the users can: delineate their areas of interest; obtain near-real-time deforestation (GLAD) and fire (VIIRS) alerts; navigate different locations to explore and create reports basedon what they find on the ground.

In addition, the web version of Forest Watchercan be further customized. It offers users options to upload their own contextual data, edit reporting templates and share created reports with team members (Forest Watcher 2021).

In association with the relevant Division Forest Offices and local council bodies, we conducted a series of workshops on GFW's forest monitoring and alert system for frontlineFGs and CFUGs. The workshops included both theoretical and practical sessions aboutthe direct use of *Forest Watcher* in forest inventory processes. In total, we trained 68 FGs and CFUG members from 34 community forests (CFs) in seven districts of western Nepal. Following the workshops, the trained

forest watchers traversed a transect length of 204 km, monitoring 6,657 hectares of CFareas from March to December 2020.

Results

Over the monitoring period (March to December 2020), 2,983 GLAD alerts were reported for deforestation. The highest number of deforestation alerts (890) was reported for the month of November, when the climate in the study area is pleasant andsuitable for deforestation activities, after a hot and rainy summer. At the district level, the highest number of GLAD alerts was reported in Jumla (1,809), followed by Dolpa (670), Jajarkot (170), Rukum East (238), Rukum West (82), Kalikot (243), and Rolpa (71).

Over the monitoring period, 285 VIIRS fire alerts were recorded within the study area (**Figure 4a**). At the district level (**Figure 4b**), 68fire alerts were reported in Jajarkot, followedby Kalikot (65), Dolpa (62), Rukum West (39), Rukum East (30) and Jumla (21). No fire alertswere recorded in Rolpa.

Discussion

It is difficult to reduce emissions from deforestation and forest degradation based on performance due to a lack of precise and consistent forest data at the global scale. The Forest Watcher application has helped local communities patrol forests by making data collection and reporting more efficient and drastically reducing the risk of errors. These data have helped improve forest conservationefforts and develop long-term effective conservation plans.

As some citizen scientists have only an elementary school education and limited English proficiency, Forest Watcher could be improved by providing translations intoNepal's various native languages. As the application is still in development, the userinterface could still be improved.

The tool dramatically reduces the timeneeded to obtain precise and reliable

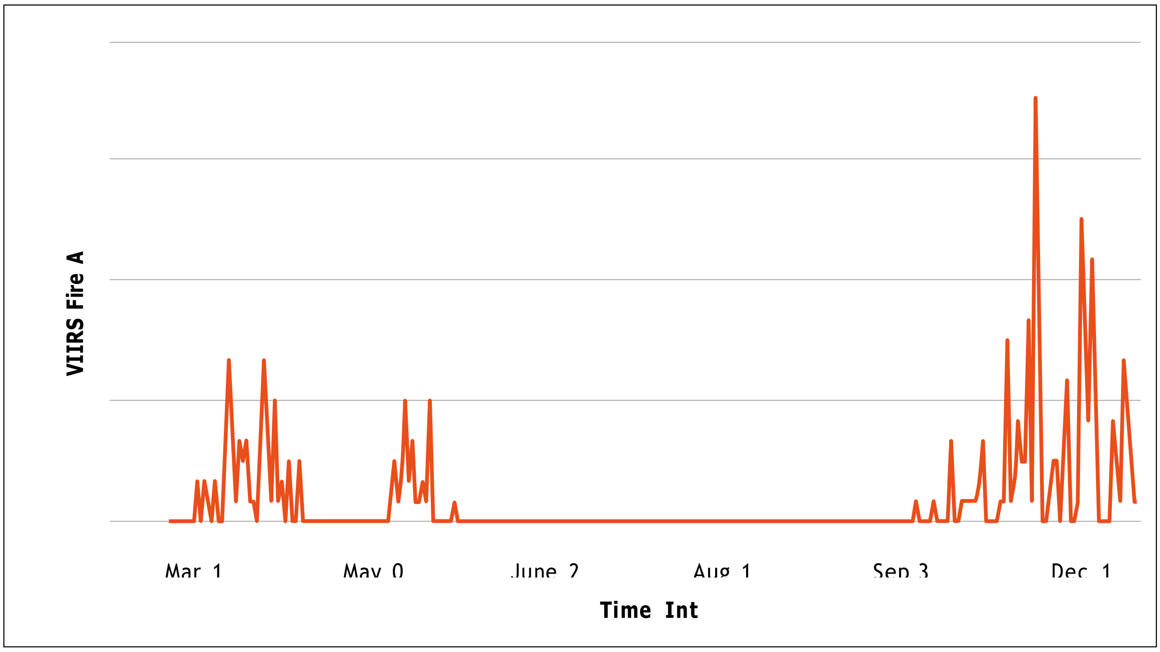

Figure 4a. Total VIIRS Fire Alerts in the study area

Source: GFW (2021)[24]

forest data. Today, anyone with an internet connection can obtain detailed and easily comprehensible information, updated every 16 days, on where and at what speed forests are disappearing or regrowing worldwide

at a spatial resolution of up to 30 meters. Governments can use this information to strengthen law enforcement, NGOs to advocate for better forest protection, and businesses to monitor deforestation in their operations and supply chains. Forest

Watcher depends on citizen scientists to help validate and ground-truth the data. Users

are encouraged to submit georeferenced comments, photos, and videos to compare on-the-ground alerts with the latest satellite images.

This application has been used to report illegal encroachment in Jajarkot and Jumla districts in western Nepal and is helping to better mobilize resources to contain forest fires in the Kalikot district. It has also been used by local forest guardians in Kalikot district to regularly monitor community forests. Traps and snares have been photographed and documented during regular patrolling.

Data are then centralized on a server, with

georeferenced comments, photos and videos of the traps and snares taken by the forest guardians.

Although tree cover loss in the study area has varied by district over the last 20 years, the overall rate appears to be decreasing. Shrestha et al. (2018) found that the districts with the most community forests experience the smallest tree cover losses and the largest tree cover gains. A total of 223 CFUGs manage community forests in Rolpa, and 101 in Jumla (Kanel et al. 2006). This highlights the effectiveness of CFUGs at improving forest cover and overall forest conditions in Nepal.

As climate change impacts precipitation, changing rain and snow patterns and shifting plant communities, fires are occurring more often, burning more intensely, and spreading more widely than ever. Such climate change-induced disasters have a cascading effect on food supply and security, agricultural production, and water availability, which can result in the loss of human lives and livelihoods. The accurate and real-time monitoring of such events using digital technologies and citizen engagement can therefore make a critical contribution to sustainable development. Data received

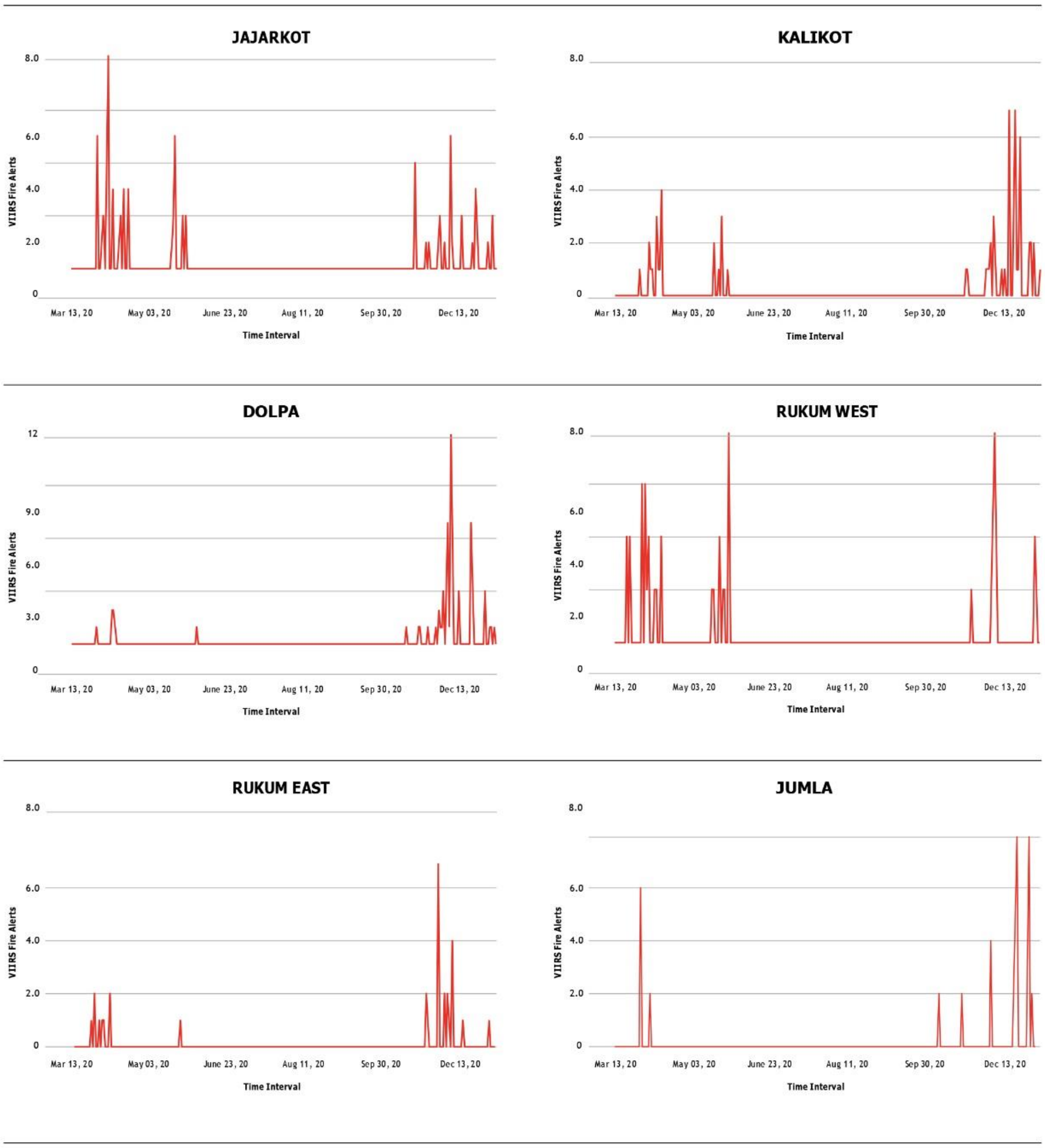

Figure 4b. District-wise VIIRS Fire Alerts

Source: GFW (2021)[25]

from forest watchers are being shared in real time with relevant CFUGs, local partnerorganizations and the Divisional Forest Offices, enabling them to react promptly

to concerns and threats recorded during monitoring. The introduction of citizen scienceinto forest management has proven very successful in Nepal.

Conclusion

A number of factors are contributing to deforestation and forest degradation in Nepal, including habitat degradation, illegal harvesting, wildfires, agricultural expansion, urbanization and infrastructure development,as well as weak state control over the land. Marginalized communities are the ultimate victims of deforestation, climate change and biodiversity degradation. Community forestry and citizen engagement in forestmonitoring and management can play a critical role in primary forest conservation and in the sustainable management of forestecosystems, thus contributing to climate change mitigation and adaptation, biodiversity conservation, food security, poverty alleviation and social inclusion.

In this context, the Forest Watcher mobile application and personal digital assistants (PDA) have significant potential to enhance community participation in the data collectionprocess, thus contributing to the successful adoption of CBFM. The integration of remote sensing technologies like Forest Watcher into local forest monitoring efforts offers considerable computational capacity at just the tap of a finger, contributing to more accurate and rapid forest monitoring while saving time and resources. Forest Watcher has enabled forest stakeholders to visualize and evaluate forestry-related information in ways that benefit the decision-making process,and it will be crucial in enhancing present conservation efforts and devising long-term effective forest conservation plans.

Acknowledgements

We would like to acknowledge Global ForestWatch for providing their Small Grants Fund Award, enabling us to conduct this work.

We are grateful to all the authorities in the Division Forest, local council bodies, forest guardians and local forest user groups for their support in successfully completing thework. We are also thankful to the editors andreviewers for their constructive comments and feedback on the manuscript.

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