News & views

Environmental sciences

Carbon stocks of African dryland trees estimated

Jules Bayala & Meine van Noordwijk

An inventory of nearly 10 billion individual trees has been compiled for the African drylands, estimating biomass and carbon stocks. The data will aid dryland restoration projects and assessments of the land carbon budget. **See p.80**

The fewer trees there are, the more important they become. This is especially true in dryland ecosystems, where scattered trees provide a range of crucial environmental services and benefits to local inhabitants. Indeed, trees will be instrumental in helping dryland communities meet many of the United Nations Sustainable Development Goals. Detailed information about trees is essential for managing and restoring dryland ecosystems, and for understanding their role in storing carbon as the climate changes, yet such data have been lacking. On page 80, Tucker *et al.*[1] address this issue by providing an inventory of carbon stocks for billions of individual trees in the African drylands.

Although dryland trees don't individually produce impressive amounts of biomass or store lots of carbon, they do affect soil quality and the water balance of the environment[2]. Dryland tree biomass therefore helps to prevent land degradation and desertification, makes the environment resilient to floods and droughts, and is a source of food, fodder, fuel and income[3]. Moreover, because the dry regions of the tropics comprise such a large area (45% of the surface area of the tropics receives less than 1,000 millimetres of rainfall per year[4]), the aggregate amount of carbon stored in dryland trees is a substantial part of the global terrestrial carbon budget[5–7].

Dryland tree density goes through phases of local decline, alternating with episodes of recovery[8,9]. Such re-greening can stem from the planting of seedlings and the preservation and nurturing of naturally regenerated trees, an approach known as farmer-managed natural regeneration[10]. Policy reform that allows farmers to benefit from trees on their land, rather than the trees being claimed by state forest managers, have thereby contributed to an increase in dryland tree cover[11,12], helping countries to meet international commitments for mitigating climate change and conserving biodiversity.

To support dryland restoration, monitoring is needed to provide data on tree distribution, density, cover, size, mass and carbon stocks, at country and regional levels. However, current approaches for generating such information were developed for forests[13], and have not been adapted for use in drylands. For example, forest methods usually provide data about total coverage, and do not characterize individual trees; but such detail is necessary for drylands, because trees are isolated and vary greatly in size and density. More broadly, establishing and updating national tree inventories requires a lot of labour, yet the statistical uncertainty associated with the data is high.

Tucker *et al.* aimed to overcome these issues by aggregating data for individual trees to provide the big picture for countries and for the whole African dryland region — an area of nearly 10 million square kilometres, extending from the Atlantic Ocean to the Red Sea, and covering the southern Sahara, the Sahel and the northern Sudanian zone. Such data have been lacking for most countries of the African drylands. The authors used artificial intelligence to identify trees in high-resolution satellite images, mapping the crown area of each tree. They then used a set of equations (generated by sampling hundreds of trees from a variety of dryland tree species) to estimate the amount of carbon stored in the foliage, wood and roots of each tree. This resulted in estimates for about 9.9 billion trees, which can be added together to assess the total above- and below-ground carbon stocks for whole regions.

The authors compared their data with estimates of carbon stocks previously derived from satellite observations or from up-to-date ecosystem models. In general, the satellite-derived estimates were higher than those in the current study. Similarly, most of the ecosystem models (11 out of 14) overestimated the amount of stored carbon, compared with Tucker and colleagues' data. This difference can be explained by the fact that previous models were not developed,

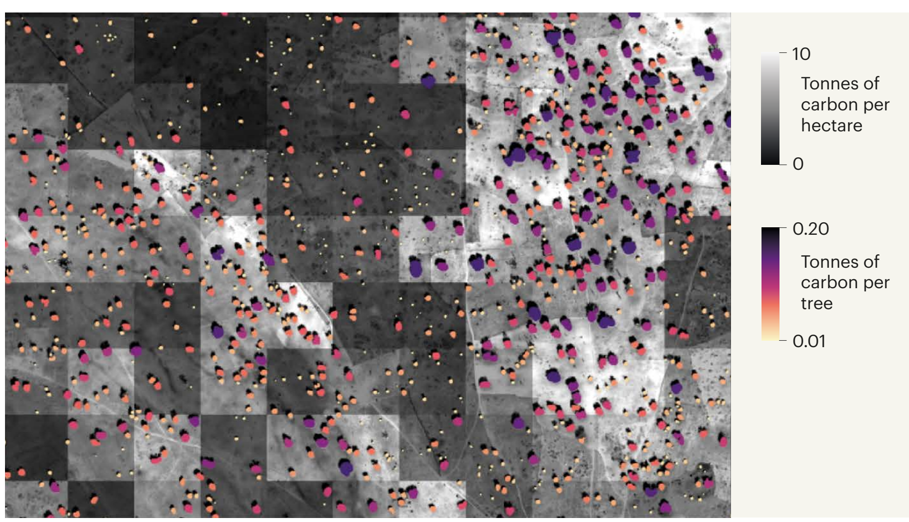

Figure 1 | A tree inventory for Khombole, Senegal. Tucker *et al.*[1] have analysed satellite images using machine-learning tools to estimate the carbon stored in nearly 10 billion individual trees in the African drylands. The data can be accessed using an online 'viewer' tool (pictured), which maps the location of trees and provides data about the carbon stored in them. The viewer also gives the carbon stored per hectare-sized square of the map. (Adapted from Fig. 5a of ref. 1.)

trained and validated using data collected from plots with sparse tree cover.

Tucker *et al.* have made their data freely available online in a 'viewer' app (see go.nature.com/3ys6nhu). This tool maps the positions of individual trees, details the amount of carbon stored in the wood, foliage and roots of each tree, and provides aggregate carbon stocks for hectare-sized squares of the map (Fig. 1). It could be used, for example, by farmers to provide up-to-date data on carbon sequestered by trees on their land, and thereby to work out credits due to them in carbon-trading schemes.

The authors make it clear that their analysis is a first step and that further updates will be needed. They would like to track the data over time to determine the effects of factors that alter ecological conditions (such as droughts and temperature anomalies), restoration projects, and the implementation of policies and regulations that affect tree growth and provision of ecosystem services, including carbon accumulation. More-accurate estimates of carbon stocks could be made by combining data from small-scale field surveys, ecosystem models, and low-, moderate- and high-resolution satellite images, and by taking into account the ecological conditions in which trees grow.

Nevertheless, the current data already form a basis for future dryland management. This will require locally customized programmes to train key players such as farmers, scientists and managers of restoration projects – because, although it is easy to measure trees, working out the next steps to promote carbon storage in the environment is not. For example, dryland trees are often pollarded (their branches are pruned to encourage dense young growth, for use as fuel or fodder), and might not produce biomass in the way that is described by general equations.

Tucker and colleagues' study is a big step forward for efforts to generate accurate data on dryland carbon stocks, and establishes a framework of scientific tools for this purpose. Encouragingly, it should be possible to improve these tools over time to provide even greater accuracy. Continuous monitoring would also be beneficial in the future, but, for maximum effectiveness, would require the establishment of 'permanent' plots (areas that undergo minimum disturbance from roaming livestock, bush fires and urbanization, for example), to enable the biomass-estimation equations to be fine-tuned to account for changes in growth rates. Establishing such plots can be challenging.

The study also raises awareness of the need for continuous monitoring of dryland trees, to inform dryland restoration projects and thereby help countries to achieve their international commitments for combating climate change and land degradation. We hope that the authors will maintain momentum to keep improving their framework, to support global and African restoration initiatives such as the UN Decade on Ecosystem Restoration, the Great Green Wall and AFR100.

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Cancer

A gut reaction can tune tumour fate

Le Li & Florencia McAllister

The discovery that molecules produced by gut microorganisms can affect immune cells, and thus the success of chemotherapy for pancreatic cancer, points the way towards the use of nutritional interventions to improve outcomes. **See p.168**

Chemotherapy is the most common treatment for pancreatic cancer that has spread to other sites in the body (metastasized). However, such treatment fails if the tumour becomes resistant to this therapy. Although new therapeutic regimens are emerging that use combinations of treatments, outcomes remain poor. If dietary interventions were to be identified that could reduce the emergence of chemotherapy resistance, and these interventions were shown to work in clinical trials, they might offer a readily available therapeutic approach. On page 168, Tintelnot *et al.*[1] present data from studies in humans and mice suggesting that certain gut microorganisms produce molecules that restore the response of tumours to chemotherapy.

Previous studies[2,3] indicate that gut-dwelling microorganisms (termed the microbiota) and tumour-associated microbes affect tumour formation, the immune response to cancer and resistance to cancer treatment. However, the mechanisms that underlie the response to chemotherapy have not been established. Microbes produce molecules from dietary components that can manipulate the immune system and ultimately affect the response to cancer therapy[4]. Understanding the mechanisms involved could lead to the use of dietary interventions to restore sensitivity to treatment.

Tintelnot and colleagues report that the gut microbiota of people with a cancer called metastatic pancreatic ductal adenocarcinoma, who were responding to chemotherapy, differed from that of individuals whose cancer was non-responsive. The authors also found that, in a mouse model of metastatic pancreatic cancer, animals that lacked their own microbiota, and that received microbiota in faecal transplants from people whose cancer responded to chemotherapy, had smaller tumours after chemotherapy than did mice given microbiota from human non-responders.

The bacteria in a tumour can determine whether treatment is successful and the clinical prognosis[5]. Moreover, gut microbes can leave the intestine, move to tumour sites and affect a cancer – either directly, or indirectly through molecules derived from microbial metabolism[6]. These metabolites can also act as chemical messengers between the gut microbiota and remote organs.

Tintelnot *et al.* tracked such molecules in people with metastatic pancreatic cancer using an analytical technique called metabolomics. They found that levels of the molecule indole-3-acetic acid (3-IAA) were higher than normal in the bloodstream of people who had responded to chemotherapy. A high level of