INDICATOR
#11 Greening of the Arctic

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Arctic Canada Trevor Bauer/iStockphoto

Arctic vegetation has undergone enormous change in the past, most notably in response to the glacial and interglacial periods of the Quaternary [1, 2]. Data from many sources and at several scales suggest that recent climate change is already affecting terrestrial Arctic ecosystems. Comparisons of historical and contemporary aerial photographs provide evidence that Arctic vegetation has already undergone significant shifts in recent decades, foreshadowing changes that are likely to come. Increased shrub cover has been confirmed in two repeat photography studies in northern Alaska [3, 4] and in a recent study in the Mackenzie Delta region of Canada [5].

Data from ground-based studies offer a more detailed view of vegetation changes. When plots established in the 1970s in Alaska were resampled, the results were consistent with a warming and drying trend, in which moist and wet community types tended to be replaced by dry community types over time [6]. At Toolik Lake, Alaska, Shaver *et al.* [7] found that graminoids (grasses and sedges), mosses, and lichens decreased and evergreen shrubs increased in abundance over a 13-year period; a subsequent study nearby [8] found that shrubs and litter had increased in abundance over eight years at the expense of lichens and total diversity. At a high Arctic site on Ellesmere Island, significant increases in biomass over the past 25 years were found in wet sedge tundra [9] and in a dwarf-shrub community [10].

Although many published data are limited to studies conducted in Alaska, unpublished reports and observations from Arctic indigenous people suggest similar changes are occurring elsewhere in the Arctic. Satellite monitoring provides a broad-scale, repeatable measure of these changes. The Normalized Difference Vegetation Index (NDVI) is a remotely sensed index of productivity, allowing spatial and temporal trends to be examined and related to changes observed on the ground.

Population/ecosystem status and trends

The area covered by Tundra Climate, as defined by the Köppen climate classification system, has been reduced by about 20% since 1980, which corresponds to a change in NDVI signatures from tundra to forest-tundra [11]. NDVI has been changing steadily since the 1980s over much of the Arctic reflecting an increase in productivity related to the increases in shrub cover (Figure 11.1) [11–13]. In addition to overall increases in productivity, NDVI data also indicate that the length of the growing season is increasing [13].

Spitsbergen, Svalbard, Norway Michel de Nijs/iStockphoto

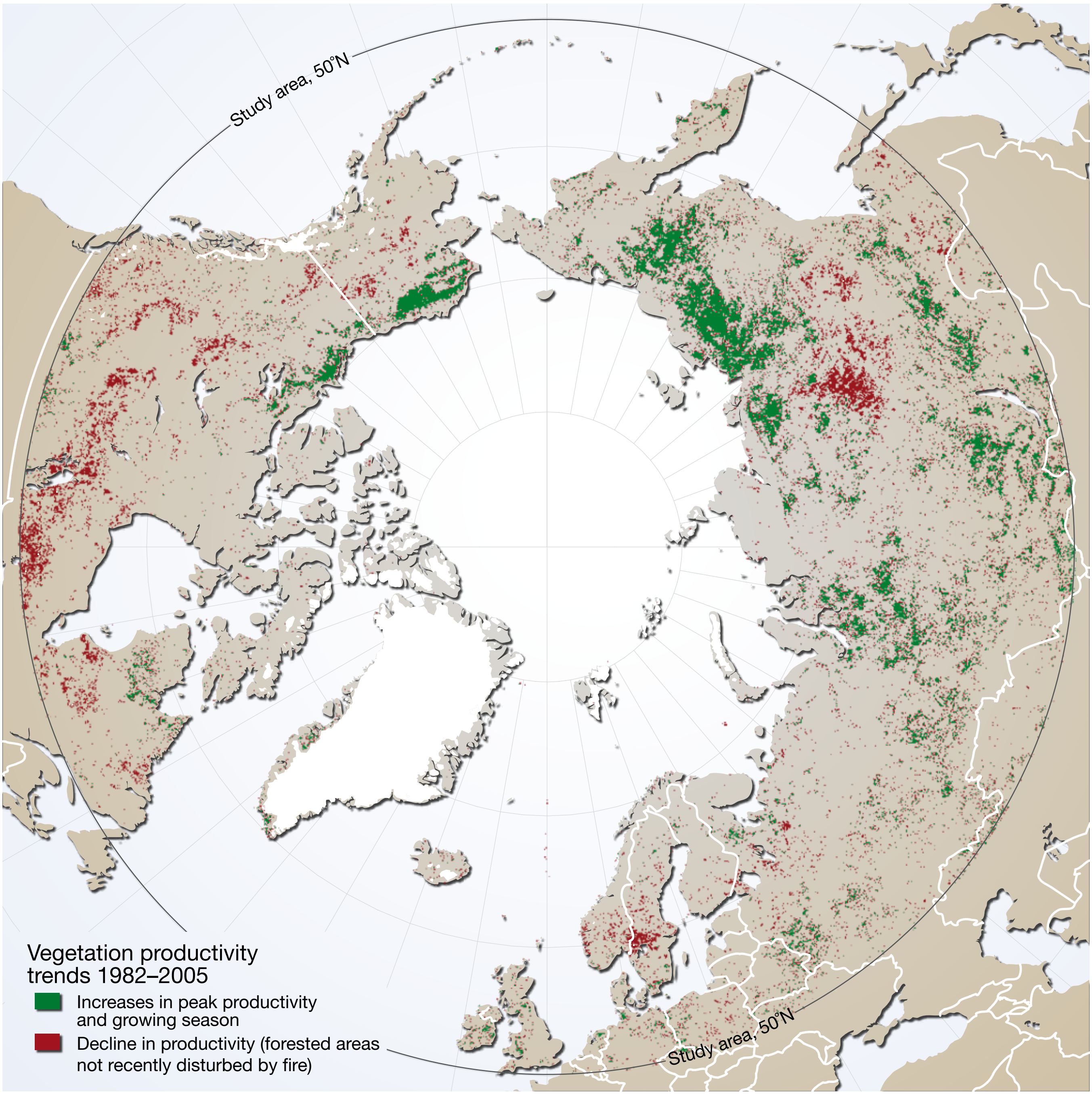

Figure 11.1: Trends in productivity derived from a 1982–2005 time series of GIMMS-G AVHRR vegetation indices (NDVI). Significant positive trends, showing as green, indicate an increase in both peak productivity and growing season. Negative trends, showing as red, represent forested areas not recently disturbed by fire that declined in productivity (Source: [15]).

Spatial variation in NDVI increases corresponds well to land surface temperature changes, with the greatest changes in NDVI occurring in Arctic areas that have experienced the most climate warming [11, 13]. Productivity levels are tightly correlated to maximum summer temperatures in tundra regions [14]. Together, these data provide strong evidence that tundra productivity is increasing regionally as a direct result of recent climate warming.

In a repeated measurement study conducted on Ellesmere Island, Nunavut, Canada, over a period of 13 years, the plant community became more productive over time, suggesting that the ecosystem is in transition (Figure 11.2) [10]. Abundance of bryophytes (mosses and liverworts) and evergreen shrubs increased, while deciduous shrub, forb, graminoid, and lichen cover did not change. The increased productivity was attributed to regional warming over the past 30–50 years.

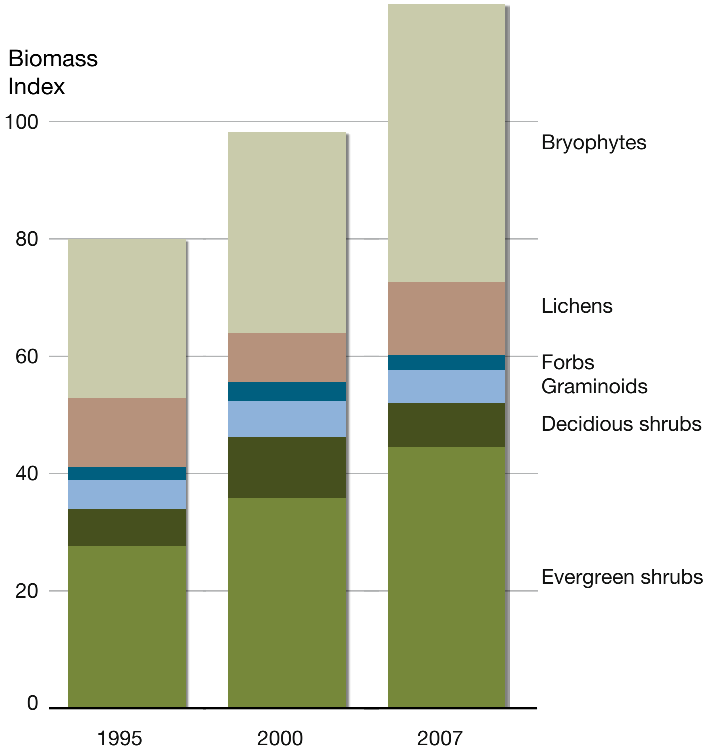

Figure 11.2: Total live vegetation, bryophytes, and evergreen shrubs increased significantly from 1995–2007 [10].

Concerns for the future

Treeline encroachment threatens the tundra at its southern margins. Some models predict that by 2100 treelines will have advanced northward by as much as 500 km, resulting in a loss of 51% of tundra habitat [16]. Expansion of white spruce forests into areas previously occupied by tundra have been documented in numerous locations in Alaska [17, 18]. Rates of treeline expansion may lag in some areas due to, for example, seed availability, disturbance frequency, permafrost changes, moisture constraints [18] and reindeer grazing activity [19].

A number of experimental warming studies conducted in the Arctic can be used in conjunction with observations and paleo-data to predict how future climate warming will affect tundra ecosystems. An analysis of warming studies found that warming generally increased productivity [20], consistent with the NDVI results. A more detailed analysis concentrating solely on Arctic sites, however, suggested increases in productivity may be transitory – warming in Arctic systems tends to lead to an initial increase in vegetative growth, followed by a boost in reproductive effort in subsequent years [21]. In addition, initial increases in growth may be greatest in herbaceous species [21] but shrub species show a greater increase in cover and biomass over the medium term [22].

Warming experiments and paleo-ecological studies also indicate that increasing temperatures are likely to change plant species composition. Research suggests that climate warming leads to rapid increases in deciduous shrubs and graminoids and decreases in mosses and lichens [22, 23]. Since more than half of all northern species are non-vascular [24], the fate of many mosses and lichens under future climate scenarios is of particular concern for biodiversity conservation. Just 1–3°C of warming can cause significant decreases in plot-level diversity within 2 years [22]. Over longer time scales, diversity throughout the Arctic may actually increase, as historically non-Arctic species migrate northwards [16]. However, the loss of endemic Arctic species and landscapes will result in an overall loss of biodiversity at the global scale.

Even within a single location, short-term responses can be poor predictors of longer-term changes in vegetation composition [25]. Vegetation changes in response to warming will also differ among sites, and at least one study indicates that long-term warming impacts may be more variable among sites than are the shorter-term responses [26]. These uncertainties emphasize the need for more long-term experiments and observational studies in a variety of locations in order to clarify tundra responses to climate warming on the greater spatial and temporal scales as measured through NDVI.