Chapter 2: Terrestrial and Freshwater Ecosystems and their Services Supplementary Material

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Table SM2.1: Attribution and assessment of uncertainties associated with key statements on observed impacts. Many human activities, in addition to greenhouse gas emissions, are affecing wild species and biome transition zones and can confound attribution of an observed change to climate change in high human impact areas. The principal non-climatic drivers are LULCC, mainly habitat destruction when natural lands are converted for agricultural use or development. The best attribution studies for observed changes in wild species and ecosystems, then, use data from areas with very little (or no) LULCC so that this effect is minimized. Lines of evidence that support confidence statements for attribution of a particular observed change to local or regional climate change (including increased atmospheric CO_2). Paleo data provides documentation of responses of species and biomes during past large climatic changes (*e.g.* across glacial/interglacial cycles of the Pleistocene). Long term observations are at least 20 years of data, ideally >50 years, such that long-term trends in biological changes can be teased apart from natural variability of both climate and of biological responses to climate variability. Experiments range from small scale laboratory studies in controlled environmental chambers, to larger mesocosm studies of manipulated communities in greenhouses or artificial ponds to large-scale manipulations of temperature, precipitation, CO_2 and other non-climatic drivers (e.g. nitrogen additions) in outdoor manipulated (planted/placed) communities and in completely natural communities to which manipulations of different drivers have been applied. Fingerprints of climate change response are a set of responses that are uniquely expected from climate change and not from other potential confounded drivers (e.g. LULCC); these are fully described in (Parmesan and Yohe, 2003)). One type of fingerprint is temporal sign-switching, in which, for example, a species' northern boundary in Europe expanded northward during the two twentieth-century warming periods (1930–45 and 1975–99), and southward during the intervening cooling period (1950–70) - a pattern that is expected from that species' responded to decadal temperature trends but not expected from documented habitat loss. Another type of temporal sign switching is found when onset of spring (leaf unfolding, flowering, breeding) follows decadal spring temperature trends, occurring earlier in warm years, later in cool years, and above and beyond yearly variability, tracking a long-term trend in spring temperatures. Sign-switching among species in a single location can also provide a fingerprint of climate change impacts when the site is at a climate zone boundary. For example, in Monteray Bay, California, where temperate and boreal species overlap, southern species were increasing in abundances and northern speces were declining over a 70 year period. Modeling approaches comprise a wide diversity of both process-based and distribution-based models. They can be back-cast and compared with observed trends - when modeled changes based upon climate as the primary driver agree with observed changes, climate change attribution is supported. Statistical analyses include those from WGI that provide attribution of regional and global climate change to greenhouse gas forcing. When biological datasets have very large sample sizes, are gathered over very long time periods and/or over large areas, in concert with complementary datasets on LULCC, meteorological data, or other drivers of interest collected over the same time periods and spatial area, statistical analyses can tease apart effects of differnt drivers and their interactions, thus providing a quantitative assessment of the role of climate change.

Key statement	**Geographic region and *Period***	**Non-climatic Drivers: Land Use and Land Cover Change (LULCC) or Other Changes**	**Lines of evidence for climate change (including increased atmospheric CO_2 as 1° driver of observed change)**					**Levels of evidence, agreement and confidence for attribution**	**References**
			Paleo data and *Long-term Observations*	**Experiments**	**Fingerprint of climate change response**	**Models**	**Statistical analyses**		
About half of all species where land use change has been a minimal driver and with long-term (>20 years) of records have shifted their ranges, with 80-90% of	Global - Varies by study. Range typically 20 - 250 years, but longest dataset is 800 years.	Minimised by study designs (1)	Polewards and upward ranges shifts have been common responses to past major climatic shifts (2). Yearly variability in polewards range boundaries for mobile birds	Translocation of temperature-limited species outside the historic range bound aries has been unsuccessful in the absence of warming and successful during warming periods (3)	Very long-term records (>50 years) demonstrate "sign-switching" in which a species poleward boundary shifts polewards during warming periods and towards the equator during cooling periods (5)	Species distribution models, Phenological models, and other process-based models driven by climate parameters have high	Yes. Warming seasonal and annual temperatures have been linked to GHG forcing at both regional and global scales (8). Multiple global meta-analyses of >4,000 species for	*robust evidence, high agreement, very high confidence*	(1) (Parmesan and Yohe, 2003) (Cross-Working Group Box ATTRIB in Chapter 1); (2) (Coope, 1995), (Cross-Chapter Box PALEO in Chapter 1); (3)(Ford, 1945;

movements being in the direction expected from regional warming trends - i.e. poleward and upward. Conclusions from prior ARs are further supported with new literature for butterflies, birds, plants, freshwater fish.			and butterflies highly significantly correlated with annual temperature variability (4)			predictive power in back-casting observed distributional changes (6)	which attribution to climate change was *medium* to *very high confidence* show from 40% to 60% of species in a given region or taxonomic group having shifted their poleward range boundary further poleward over the past 20-120 years (8)		Willis et al., 2009)(2.6.5.1); (4) (Dennis, 1993; Parmesan and Yohe, 2003); (5) (Parmesan and Yohe, 2003); (6) (Chuine and Régnière, 2017; Platts et al., 2019); (7) (WGI AR6 2021); (8) (2.4.2, Table 2.2)
About 2/3 of all species with long-term (>20 years) of records have shifted the timing of spring events in directions expected from regional winter and spring warming.	Global - Varies by study. Range = 20 - 400 years	NA / Photoperiod is an important cue for some species, which would show up as either no change in phenology over time, or where both photoperiod and temperature are drivers, photoperiod cues may tend to counter temperature cues (1)	Yearly variability in spring emergence,flight and migrationof birds and butterflies and leaf-out and, flowering of plants is highly significantly correlated with spring temperature variability (3)	Controlled experiments demonstrate that temperature has large effects on timing of spring events for many species (2)	Very long-term records (>50 years) demonstrate "sign-switching" in which a species shifts to earlier spring events during warming periods and later spring events during cooler periods (4)	Phenological models based on temperature have good predictive power in back-casting observed phenological change; model performance is improved if photoperiod is included, and even better if abiotic factors are included (5)	Yes. Warming spring temperatures have been linked to GHG forcing at both regional and global scales (6). Multiple global meta-analyses all show from 48% to 92% of species in a given region or taxonomic group having shifted towards earlier spring timing in recent decades; exception is seabirds that have been stable (7)	*robust evidence, high agreement, very high confidence*	(1) (Piao et al., 2019; Ettinger et al., 2021); (2) E.g. (Craufurd and Wheeler, 2009; Wolkovich et al., 2012; Piao et al., 2019); (3) (Dennis, 1993; Gordo, 2007; Amano et al., 2010; Piao et al., 2019), (4) (Parmesan and Yohe, 2003); (5) (Piao et al., 2019); (6) {WGI AR6 2021}; (7) (Section 2.4.2.4, Table 2.2) Freshwater: (Adrian et al., 2006; Blenckner et al., 2007; Adrian et al., 2009)
For species that require winter	Northern Europe and	NA / Photoperiod	NA. Yearly variability	orange tip, vernalization of plants		Models based on seasonal	Yes. Fall and winter warming	*medium evidence,*	(1) (Gill et al., 2015; Piao et

chilling, winter warming has countered spring warming, resulting in either delayed spring events or no change. When these species are taken into account, it is estimated that 92% of species in these studies have responded to regional warming trends	USA - Varies by study (>20 years)	and vernalization requirements interact (1)	in break of diapause and dormancy highly significantly correlated with variability of fall and winter temperatures (3)	(UEA group) - demonstrate high heritability (strong genetic basis). Metabolic pathways understood for some species (2)		temperature sensitivities of individual species have good predictive power in back-casting observed phenological change (4)	has been linked to GHG forcing at both regional and global scales (5). *None to date.*	*high agreement, high confidence*	al., 2019; Ettinger et al., 2021); (2) E.g.: (Friedman and Willis, 2013; Stålhandske et al., 2017); (3) (Cook et al., 2012a; Cook et al., 2012b; Stålhandske et al., 2017); (4) (Cook et al., 2012a; Cook et al., 2012b; Xie et al., 2015); (5) {WGI AR6 2021}; (Section 2.4.2.5)
Wildfire has burned increasingly extensive areas, increasing nine-fold in 32 years, driven more by the increased heat and aridity of anthropogenic climate change than by non-climate factors	Western North America - 1984-2017	Population density, roads, built area, analysed but less important	Field and remote sensing measurements of burned area: Western USA burned area increased >900%, 1984-2015; Alaska burned area in 2015 was the second highest in the 1940-2015 record; British Columbia, Canada, burned area in 2017 was the highest in the 1950-2017 record. Weather station *measurements of climate: Western USA temperature increased 1.5°C, 1920-2018, summer precipitation*			Numerical models of wildfire as a function of climate and non-climate variables, calibrated by historical data, run for actual observed values and compared to model runs in which temperature remains unchanged. Western USA: anthropogenic climate change doubled burned area over natural burning, accounting for	Increased temperature and decreased summer precipitation detected and attributed to anthropogenic greenhouse gas forcing. Anthropogenic climate change accounts for half the magnitude of a regional drought, 2000-2020, reducing soil moisture to its lowest levels since the 1500s. *Correlation of burned area to climate variables (temperature, precipitation, relative humidity, evapotranspiration*	*high evidence, high agreement, high confidence*	(Abatzoglou and Williams, 2016; Partain et al., 2016; Holden et al., 2018; Kirchmeier-Young et al., 2019; Mansuy et al., 2019; Williams et al., 2020) + refs in section {2.4.4.2}

			decreased 12%, 1984-2016		49% (32-76%, 95% confidence interval) of cumulative burned area, 1984-2016; Alaska: Anthropogenic climate change accounted for 34-60% of 2015 burned area; British Columbia: Anthropogenic climate change increased 2017 burned area 7 to 11 times over the area of natural burning	*) outweighed local human factors (population density, roads, and built-area)*		
Tree mortality has increased substantially, as much as doubling in 52 years, driven more by the increased heat and aridity of anthropogenic climate change than by non-climate factors	North America, Africa - *ca. 1945-2007*	Multivariate and bivariate statistical analyses of population density, roads, timber harvesting, livestock grazing, increased tree density, fire suppression, toppling of large trees, analysed but less important	Field surveys of trees: western U.S. tree mortality doubled, 1955-2007; African Sahel tree mortality 18%, 1954-2002; southwest Morocco tree mortality 44%, 1970-2007; weather station measurements show significant increases in temperature and decreases in precipitation			Increases in temperature and changes in precipitation detected and attributed to anthropogenic greenhouse gas forcing. *Canonical correlation analyses of climate and non-climate factors found climate change outweighed other factors; other cases correlation analyses of climate factors significant, non-climate* factors non-significant.	*medium evidence, high agreement*	(Desanker et al., 2001; van Mantgem et al., 2009; Gonzalez et al., 2012; le Polain de Waroux and Lambin, 2012) [many other cases detected (Allen et al., 2010; Allen et al., 2015; Bennett et al., 2015; Martinez-Vilalta and Lloret, 2016; Greenwood et al., 2017; Hartmann et al., 2018) but not formally attributed + refs

								in section {2.4.4.3}
Vegetation biomes have shifted significantly towards the poles or the Equator or upslope at 19 sites in boreal, temperate, and tropical ecosystems, caused more by increased temperatures and changes in precipitation of anthropogenic climate change than by non-climate factors	Global - 1500-2008	Research in some areas conducted multivariate statistical analyses of climate and other factors, population density, roads, other non-climate factors analysed but less important; research at other areas selected sites with no substantial human land use change	Field surveys show significant changes of vegetation species locations and densities, boreal forest shifting into tundra, subalpine forest shifting into alpine grassland, broadleaf forest shifting into coniferous forest, grassland shifting into woodland; Weather station measurements show significant increases in temperature and changes in precipitation		*see section text*	Increases in temperature and changes in precipitation detected and attributed to anthropogenic greenhouse gas forcing. Canonical correlation analyses of climate and non-climate factors in some areas; correlation analyses of climate factors significant, non-climate factors non-significant in some areas; no substantial local human land use change in some areas.	*high evidence, high agreement, high confidence*	(Beckage et al., 2008) (Brink, 1959) (Desanker et al., 2001; Lloyd and Fastie, 2003; Danby and Hik; Dial et al., 2007; Devi et al., 2008; Kullman and Öberg, 2009; Gonzalez et al., 2010; Leonelli et al., 2011; Gonzalez et al., 2012; Kirdyanov et al., 2012) (Luckman and Kavanagh, 2000) (Payette et al., 1985; Wardle and Coleman, 1992; Suarez et al., 1999; Penuelas and Boada, 2003; Millar et al., 2004; Walther et al., 2005; Payette, 2007; Settele et al., 2014) + refs in section {2.4.3.1; 2.4.3.2; 2.4.3.3–9; 2.4.5}
Beetles & moths shifting poleward and upward has brought new pest species into some forests	North America, Europe and Eurasia. Time period varies by study.	Not directly assessed, but occurring in both areas of high LUC and protected areas	Direct observations of insect pest outbreaks have been recorded since the mid-	controlled temperature experiments link warming winters to lower insect mortality, and increased growing season length to	*see section text*	*see section text*		refs in section {2.4.2.1; 2.4.4.3; particularly 2.4.4.3.3}

	Datasets start in mid-1800s to present		1800s for many temperate and boreal forests in the northern hemisphere	increased number of generations per year, which leads to large increases in insect abundances in late growing season					
Shift in forest composition has occurred due to species-specific differences in response to increasing drought	*see section text*	*see section text*	*see section text*			*see section text*	*see section text*		(Anderegg et al., 2016)
Increased tree mortality has occurred globally, in boreal, temperate and tropical systems, in response to increased drought, wildfire and insect pest outbreaks	Global - Timespan varies by study. Observational datasets available from mid-1800s to present. Treerings provide data going back hundreds of years	For many studies, land use change is an important driver. For some studies, LUC is minimal (1) pest outbreaks are important drivers, but impacts have been exacerbated by heat/drought induced tree stress (2)	tree-rings provide very long-term data, that overlaps with observational data starting in mid-1800s			*see section text*	*see section text*	*high evidence, high agreement, high confidence*	refs in section {2.4.4.3}
Diseases wildlife/humans									
Newly emerging vector-borne diseases (dengue, chikungunya, Japanese encephalitis, malaria, visceral leishmaniasis) and their vectors (*An.spp., Aedes albopictus, Ae. aegypti, Culex quinquefasciatus, C.*	South Asia (Nepal) - *Dengue (2004-present) / Chikungunya (2013-present) / Japanese Encephalitis (1995-present) / Visceral Leishmaniasi*	JE has + association with irrigated land, agriculture, land use / Malaria: incidence decreased in lowlands with free distribution of long-lasting	Dengue: 1st reported case in Nepal in 2004, outbreak in 2006, then expansion to new areas in 2008, spread to highlands in 2010. Chikungunya: The first autochthonous cases of chikungunya virus were reported in	Dengue: EIP = 15 days at 25°C & 6.5 days at 30°C (Rohani et al., 2009) / Narrower DTR decreases EIP or increases susceptibility of mosquitoes to infection (Lambrechts et al., 2011)	Dengue: Increased number of cases in highlands of Himalayan region in temperate to subalpine areas (Acharya et al., 2020) / min temp highly sig correlated with dengue cases in Chitwan district (Tuladhar et al., 2019) / increased nightly temps during the monsoon months correlated with increased transmission ($p<0.05$)	-	Higher warming rates in high-elevation areas compared to lowlands -- warming rate of Nepal is higher than global average / decreasing trends of cool days & increasing trends of warm days in higher elev. / increasing trends	*high confidence*	(Dahal, 2008; Lambrechts et al., 2011; Dhimal et al., 2014a; Pun et al., 2014; Dhimal et al., 2015a; Pandey et al., 2015; Pandey et al., 2017; Shrestha et al., 2018; Shrestha et al., 2019; Tuladhar

tritaeniorhynchus) are appearing in higher elevation and non-endemic regions of Nepal. Climate change will intensify VBD epidemics in mountain regions of Nepal.	*s (2009-present)*	insecticidal nets (LLINs)	2013 (Pun et al., 2014) and have expanded their geographic range in Nepal (Pandey et al., 2015; Pandey et al., 2017) Japanese Encephalitis: introduced in 1970s to S. Nepal but 1st epidemic in 1995 in Kathmandu valley, shifted to mountain districts after 2005. Visceral Leishmaniasis: 1st case in hilly non-endemic region in 2011, now found in hill & mountain regions previously considered non-endemic. Malaria: reported in 1969 at 1800+ m., and An. maculatus recorded up to 3100 m.; most malaria cases below 1200 m. in 1978-80 (originally confined to forest areas of lowlands); now in hills and mountains 2000+m		from 2010-2019 (Gyawali et al., 2020).		of max temps & more warming in winter compared to other seasons /statistically sig. warmind trend of max temps / sig increase in annual mean temp highly influenced by max temp / increasing trends in heavy prec. events. Dengue: Chitwan district, Nepal study 2010-2017: Max temp sig correlated with cases through lag 1-3 month lag / Min temp sig correlated with cases 0-3 month lag w/ strongest correlation at lag 2 / min temp strength corr. higher than max temp / rainfall sig correlated with cases 1-3 mos. lag & highest a lag 2 mo. (Tuladhar et al., 2019)		et al., 2019; Gyawali et al., 2020; Liu et al., 2020; Phuyal et al., 2020; Dhimal et al., 2021a; Dhimal et al., 2021b)
Haemonchosis (Haemonchus contortus) worm of sheep / H. contortus was	Northeastern Europe (UK, Scotland), 1989-2006	No intensification of sheep farming found up to 2006	Sig increase in diagnosis rates from 1989-2006 (p = 0.001) but also showed some	Optimal temps for development and growth are between 25-37°C (more adapted to sub-tropics	Sig increase in diagnosis rates in northern study regions (Scotland, N UK, & Midlands) from 1977-2006; Sig positive trend	Increases in summer temps increase mortality and offset the	Mean annual temperature increased w/ temp increasing earlier and more	*robust evidence, high agreement,*	(Smith, 1990; O'Connor et al., 2006; van Dijk et al., 2008; van Dijk et al.,

endemic to southern England but is now documented in Scotland and has an extended transmission season. Benefits of increased developmental rates outstrip the disadvantages of increased death rates during some times of the year, particularly benefiting from increased developmental opportunities in spring and early summer; besides climate, interaction with hosts will be very important (van Dijk et al., 2010).		during time period of increased disease incidence (van Dijk et al., 2008). Effective anthelmintics were still available during the latter years of the study and antihelminthic resistance would not affect the seasonality of the disease (van Dijk et al., 2010). Sig increases in parasite abundance documented in colder northern parts of Great Britain but not warmer southern parts (anthelmintic resistance would be expected to increase abundance in the south as well) (van Dijk et al., 2010).	periods of significant decrease (1992-1996, 2002-2006) meaning there is high variability in the system (van Dijk et al., 2008). Highly sig increase in disease incidence starting in late 1990s-2006 (p <= 0.005, Spearman's rho > 0.450) (van Dijk et al., 2010).	and tropics) but it can survive from 10-40°C (O'Connor, 2006). The min. dev time decreased as temp increased from 16 days at 10°C to 2.5 days at 37 C (Smith, 1990).	for Nov & Dec suggesting greater autumn haemonchosis recently (van Dijk et al., 2008).	increased development rate (Rose et al., 2015).	significantly in spring months; sig increase in rainfall in April (van Dijk et al., 2008). "Overall, the observed temperature-mediated increases in cercarial output are much more substantial than those expected from basic physiological processes, for which 2- to 3-fold increases are normally seen" was stated in an analysis examining cercarial production of different species of trematodes in temperature experiments - review paper of 20 studies (Poulin, 2006). Sig positive relationship between GIN infection level (GIN: Nematodirus spp., Haemonchus contortus, Teladorsagia circumcincta, Trichostrongylus spp., Chabertia ovina, Bunostomum spp.) with max humidity and sig negative relationship with solar radiation	*high confidence*	2010; Rose et al., 2015)

							during 30 day period preceding prepatency (when free-living stages are developing in the field). (Martínez-Valladares et al., 2013)		
Teladorsagia circumcincta (brown stomach worm), *Trichostrongylus vitrinus, Tr. colubriformis, Tr. axei* (round worms) found in sheep and goats are spreading northward in Europe and expanding their transmission season.	Northwestern Europe (UK, Scotland), 1975-2006 (van Dijk et al., 2008)	No intensification of sheep farming found up to 2006 during time period of increased disease incidence. Effective anthelmintics were still available during the latter years of the study and antihelminthic resistance would not affect the seasonality of the disease. (van Dijk et al., 2008)	Sig increase in diagnosis rates from 1975-2006 (p < 0.001), Highest rate of increase occurred between 1997-2006; sig increases in diagnostic rates over most of the UK except the most northern part (Scotland); Sig positive trend from north to south (van Dijk et al., 2008). Transmission opportunities extended into autumn in Scotland while sig decreases in disease were observed in the spring in the areas south of Scotland (van Dijk et al., 2010). Highly sig increase in disease incidence starting in late 1990s-2006 (p <= 0.005, Spearman's rho > 0.450) (van Dijk et al., 2010).	Accumulation of infective stages from successive generations of adult parasites is accelerated at higher temps, leading to higher parasite abundance and increased risk of disease from midsummer onwards (Armour, 1986; Barger, 1997). Low temperatures (<10 C) reduce development of larvae & reduce hatching of *Tr. colubriformis, Tr. rugatus* while *Tr. virtrinus* could develop successfully to the infective stage in temps <10 C (Beveridge, 1989); 30 C reduced number of larvae from 3 *Trichostrongylus* spp. (Beveridge, 1989). Tr. colubriformis does not develop when soil temps <10 C and air temps <13 C (Gibson and Everett, 1976; Levine and Andersen, 1973). *Tr. colubriformis* was recovered in low	Mean peak month became sig later in southern most region showing later shift in seasonality (1977-2006) and sig declines in the spring months (1977-2006) (van Dijk et al., 2008).	Increase in temps resulted in increased development rates for *T. circumcincta* leading to year-round development. (Rose et al., 2015).	Mean annual temperature increased w/ temp increasing earlier and more significantly in spring months; sig increase in rainfall in April (van Dijk et al., 2008). "Overall, the observed temperature-mediated increases in cercarial output are much more substantial than those expected from basic physiological processes, for which 2- to 3-fold increases are normally seen" was stated in an analysis examining cercarial production of different species of trematodes in temperature experiments - review paper of 20 studies (Poulin, 2006). Sig positive relationship between GIN	*robust evidence, high agreement, very high confidence*	(Levine and Andersen, 1973; Armour, 1974; Gibson and Everett, 1976; Southcott et al., 1976; Salih and Grainger, 1982; Beveridge et al., 1989; Barger, 1997; Poulin, 2006; van Dijk et al., 2008; van Dijk et al., 2010; Martínez-Valladares et al., 2013; Rose et al., 2015)

				numbers when temps were between 1.3-15 C (Southcott, 1976). Mean time until hatching took 19.1 days at 10 C and increased with warming temps to 1 day at 25 C (Salih and Grainger, 1982)			infection level (GIN: *Nematodirus* spp., *Haemonchus contortus, Teladorsagia circumcincta, Trichostrongylus* spp., *Chabertia ovina, Bunostomum* spp.) with max humidity and sig negative relationship with solar radiation during 30 day period preceding prepatency (when free-living stages are developing in the field). (Martínez-Valladareset al., 2013)		
Fasciolosis risk caused by *F. hepatica* (exposure, prevalence, outbreaks, geographic emergence) significantly increased or appeared in new areas over time. There are broad trends towards increased risk. *Fasciola hepatica* is a liver fluke that infects many different animal species (domestic primary hosts: sheep, cattle; other domestic	Europe: 1977-2006, UK (van Dijk et al., 2010), 2006-2001, Spain (Martínez-Valladares et al., 2013); 2000-2013, Italy (Bosco et al., 2015)	Antihelminthic drug resistance may be contributing to disease increases in some areas; however, drug resistance would not be expected to alter the seasonality by extending the fall grazing, transmission season. The government funded the installation of modern irrigation systems in	East Anglia, UK: New outbreaks and increased disease incidence from 2001-2003 occurred on farms with no prior history of disease; only sporadic disease since the 1960s. Disease was only first recorded in 1996 during the study period of 1993-2003 (Pritchard et al., 2005). Highly sig increase in disease incidence starting in late 1990s-2006 ($p <= 0.005$, Spearman's rho > 0.450) (van	*Lymnaea viridus* snails infected with *Fasciola hepatica* shed cercariae more quickly, for longer durations, and in higher numbers ($p<0.001$) at higher temperatures (Lee et al., 1995).	-	-	Avg annual rainfall in East Anglia from 1970-2000 (605.6 mm) compared to outbreak years of 2001-2002 (781.1) increased by 175.5 mm and was higher in summer months of July and August [no stat testing] (Pritchard et al., 2005). Increasing min humidity and precipitation was associated with increases in epg in Spanish study from 2006-2011 during 30 day period preceding	*medium-robust evidence, high agreement, high confidence*	(Lee et al., 1995; Pritchard et al., 2005; van Dijk et al., 2010; Martínez-Valladares et al., 2013; Bosco et al., 2015; Caminade et al., 2015)

hosts: goats, alpacas; wild hosts: rabbits, nutria, red deer (*Cervus elephus*).		Castilla and Leon, Spain, since the 1990s which may be increasing humidity (not statistical analysis carried out) (Martínez-Valladares et al., 2013). However, No intensification of sheep farming found up to 2006 during time period of increased disease incidence in UK (van Dijk et al., 2008).	Dijk et al., 2010). Spanish province of León showed prevalence increasing in sheep flocks from 14.67% (1986-87) to 26.7% (1992-93) to 60.5% (2011) (Martínez-Valladares et al., 2013).		prepatency (when free-living stages are developing in the field)(Martínez-Valladares et al., 2013). Sig increase in temperature, rainfall, and # rainy days during outbreak in Italy (p < 0.001) (Bosco et al., 2015).		
Nematodirosis (*Nematodirus battus, N. filicollis, N. spathiger*) in sheep is increasing.	Northeastern Europe (UK, Scotland), 1975-2006	No intensification of sheep farming (van Dijk et al., 2008). Effective anthelmintics still available during the latter years of the study and antihelminthic resistance would not affect the seasonality of the disease. There has been no antihelminthic	Sig increase in 2002-2006 compared to diagnosis rates from 1975-2002 (p <= 0.011) (van Dijk et al., 2008). Highly sig increase in disease incidence starting in late 1990s-2006 (p <= 0.005, Spearman's rho > 0.450) (van Dijk et al., 2010).	Sig increase in Scotland (most northern portion of study area) w/ no significant or only marginal rises in diagnostic rates in southern areas (Wales, SW Britain) from 1975-2006. Sig positive trend from south to north; Cases were first recorded in December in 1999 (van Dijk, 2008).	Mean annual temperature increased w/ temp increasing earlier and more significantly in spring months; sig increase in rainfall in April (van Dijk et al., 2008).	*medium-robust evidence, high agreement, high confidence*	{van Dijk, 2008; van Dijk, 2010

		resistance recorded for N. battus (van Dijk et al., 2010). Sig increases in parasite abundance documented in colder northern parts of Great Britain but not warmer southern parts (anthelmintic resistance would be expected to increase abundance in the south as well) (van Dijk et al., 2010).								
Midge-borne bluetongue virus is expanding into new geographical areas as higher temperatures make new areas habitable for both the vectors and virus. Bluetongue virus infects ruminants (sheep, cattle, deer, and goats) and is vectored bu midges of the genus Culicoides.	Northern Europe (2006 and later)		BTV spreading northward in Europe during the 2000s (Carpenter et al., 2009).				A comprehensive deterministic model set takes into account multiple vector and host state variables (incubating, infectious, susceptible, recovered) and other vector/host population parameters (birth rate, mortality rate), air temperature (seasonality), host immunity,		*limited-medium evidence, medium agreement, low confidence*	(Thornley and France, 2016; Tryland et al., 2018)

						and vertical tranmission to offspring over time on a farm hypothetically set in aouthern England. Climate warming increases air temperature and reduces vector mortality (Thornley and France, 2016).			
The roundworm Setaria tundra, a species of filaroid nematode, is a vector-borne disease spread by Aedes and Anopheles mosquitos, which infects reindeer (Rangifer tarandus), roe deer (Capreolus capreolus) and moose (Alces alces). Outbreaks were found to be driven by mean summer temperatures of 14°C or higher with increasing morbidity and mortality lagging to the following year. These high summer temperatures reflect a tipping point that impacts	Nordic regions of Europe: Finland (1961-2004); Lapland (1979-2015)		Outbreaks recorded back to the 1970s in cervids in Nordic regions of Europe. Meat inspections dating back to the 2000s in Finland show reindeer meat condemnation increased from 4.9% in 2001 to 40.1% in 2003 in Oulu province with the outbreak moving northward by 100 km. There was a massive increase in reindeer viscera condemned in both northern and southern Lapland (Laaksonen, 2010).	"Warmth decreases the time required for larval development of S. tundra larvae" (Laaksonen et al., 2009)		GLMs showed that the occurrence of an epidemic lagged and increased with mean summer temperatures(b = 6.60 ±3.39 (s.e.); P = 0.0004) but "moribidity manifests the following summer only if the weather conditions are still favorable" (Laaksonen et al., 2010). "In southern and central Lapland, our model predicted an increasing tredn from 1979-2015 for both the duration oif the		*medium evidence, high agreement, medium confidence*	Filariasis (Laaksonen, 2010; Laaksonen and Oksanen, 2010; Laaksonen et al., 2010; Haider et al., 2018; Tryland et al., 2018)

Aedesvector abundance, Setaria tundrainfection, and reindeer flocking behavior to mosquito rich wetlands.						effective transmission period of S.tundra ($P<0.001$) and for the potential number of L3 S. tundra larvae being transmitted from an infectious reindeer ($P<0.001$)" (Haider et al., 2018)			
Elaphostrongylosis is a snail-borne helminthiasis caused by *Elaphostrongylus rangiferi*, which infects reindeer (*Rangifer tarandus*) has caused recent outbreaks and has development increase with temperature.	Nordic regions of Europe (1974-1988)			*E. rangiferi* development in snails is dependent on temperature and increases with increasing temperatures (Halvorsen and Skorping, 1982).	Norwegian outbreak over warm summer in 2018 affected more age classes and had unusual phenological timing (Deksne et al., 2020)	Cross correlation time series analysis found *E. rangiferi* abundance increased with increases in summer temperature (Halvorsen, 2012).		*limited-medium evidence, medium agreement, low confidence*	(Halvorsen et al., 1979; Halvorsen, 2012; Handeland et al., 2019; Deksne et al., 2020)
Tick-borne encephalitis virus and its vector tick species have expanded to higher altitudes and latitudes because of phenological changes: warmer autumns, milder winters, and earlier spring. The expansion of Ixodes persulcatus	Northern Europe: Stockholm and Uppsala, 1984-2008 (Haernig et al., 2008); Sweden, Stockholm county, 1960-1998 (Lindgren et al., 2001) and Asia: Russia, Archangelsk	Increases in human population were not analyzed in some studies but in others, for instance, the Komi Repbulic study by Tokarevich (2017) found only a 4% population increase	No uptrend found in TBE virus prevalence in ticks examined from 1996-1999 & 2002-2009. BIR (tick-bite incidence rate) and TBE incidence examined from 1980-2009: TBE incidence found to increase 40-fold in 30 years from 0.1	Entomological and weather survey plots of ticks in southern Prague, Czech Republic from 2001-2004 tracking tick behavior and air and soil temp., humidity, prec., soil moisture, wind speed - temp good predictor as long as extreme prec/humidity/moisture conditions not	An entomological and epidemiological analysis of monthly tick survey data from 1992-2009 found ticks expanded northward and eastward and increased in population size in AO, Russia (Tokarevich et al., 2011). Tick bite season increased from 4 to 6 months and substantial N shift of tick bites reported(Tokarevich et al., 2017).	Simple 2 and 3 parameter time series models of Ixodes ricinus host-seeking behavior and weather were constructed in Czech Republic, $R>0.612$(Daniel et al., 2006)	Warmer and prolonged warm seasons increase TBE incidence (Multiple regression model results: R2 = 0.58, $p<0.0001$, Full model: increases in disease incidence associated with 2 mild winters, temperatures favouring spring development (8-	*high evidence, high agreement, very high confidence*	(Lindgren and Gustafson, 2001; Kutz et al., 2005; Daniel et al., 2006; Tokarevich et al., 2011; Hoberg et al., 2013; Kutz et al., 2013; Tokarevich et al., 2017)

is the primary driver for increase TBE incidence in the Arkhangelsk olast region of Russia even while overal TBE incidence decreased for all of Russia. Northern regions are documenting new cases of disease and vectors while southern and central areas in the north are experiencing drastically higher disease incidence rates and biting rates. Ixodes ricinus ticks and TBE incidence increased in the Czech Republic and appeared in high elevation areas (Šumava and Krkonoše Mountains) not previously observed.	Oblast (AO), 1980-2009 (Tokarevich et al., 2011), Komi Republic, 1970-2011 (Tokarevich et al., 2017) ; Czech Republic: 1953-1976, 1982, 1992, (tick surveys), 1965-2001: TBE incidence (Daniel et al., 2004)	between 1970-2011.	in the 1980s to 9.9 in 2009. Tick-bitten inhabitants increased from 284 in the 1980s to ~4000 in the 2000s. Tick bites were newly reported in central and northern districts after 2000. Length of tick-bite reporting period increased 20-fold in N region, 2-fold in Central, and 1.5 fold in S region. (tick bites are mandatory reporting) (Tokarevich et al., 2011). Monthly tick abundance data collected from 1970-2011 in windows from 1970-71, 1974-80, 1982-84, 1986-92, 200-2003, 2005-2011. TBEV only found in ticks in S and C regions of Komiin 2011 but not before. 23-fold increase in patients seeking care for tick bites from 1992-2011.TBE incidence increased from 0.12 (1970-83) to 2.17 (2009-2011) (Tokarevich et al., 2017).	encountered (Daniel et al., 2006)			10°C) and extended autumn activity in the year prior to incidence year, and temperatures allowing tick activity (5-8°C) early into the incidence year) (Lindgren and Gustafson, 2001). Mean annual temperature change in AO, Russia: +2.0°C in 2000s compared to 1960-1989; regression analysis of temperature and TBE incidence (R ranging from 0.5-0.77 depending on region and exclusion criteria, p<0.01) found strong correlation between increases in temperature and TBE incidence rate (Tokarevich et al., 2011). Sig increase in avg annual air temp between 1989-95 resulted in a 0.25 TBE incidence rate increase / strong correlation coefficient of 0.77 for all RK (p<0.0001) (Tokarevich et al., 2017).		

West Nile disease incidence increased due to temperature and has moved further north in Eurasia.	(eastern Europe) Russia - *1999-2012*	Decreased incidence was observed in the year following an outbreak.	WND first reported in Russia in 1999. Outbreaks were associated with higher summer temperatures and mild winters.	Temp increases shorten gonotrophic period (GP), and increases reproduction of Culex spp., and decreases extrinsic incubation period (EIP) of the virus.			Mean temp in winter (Dec-March) (R=0.59), mean temp in summer (July-Sep) (R=0.67), hours temp above 25°C (R=0.70), mean humidity in 2nd and 3rd quarters (R= -0.51), mean atm. pressure in 3rd quarter (R= -0.71)	*limited evidence, med-high agreement, low-medium confidence*	(Platonov et al., 2008; Platonov et al., 2014; Mihailović et al., 2020)
Taxonomic-specific statements				-	-	-	-		
Climate change induced warming leads to shifts in thermal regime of lakes	Boreal - Past >40 years	Eutrophication / Trophic state of lakes(1)	In situ monitoring in real time; decadal observations >40 years		Polymictic lakes (regularly mixed throughout summer) may become dimictic more frequently; dimictic lakes (regularly stratify throughout summer) may have a greater tendency to become monomictic; and monomictic lakes (differ to dimictic lakes in that they do not freeze over in winter) may tend to become oligomictic (thermally almost stable, mixing only rarely; mostly tropical lakes) (2)	yes, observed changes based on long-term empirical data match model projections; Kirillin 2010, Kirillin & Shatwell, 2016	One dimensional lake model, statistical analysis, numerical models.	*Robust evidence* that climate change is one of the primary driver. Planktonic events can contribute to polymictic-dimictic regime shifts in temperate lakes, *high confidence*	(1) (Shatwell et al., 2016); 2 (Kirillin, 2010; Kirillin and Shatwell, 2016; Wood et al., 2016; Ficker et al., 2017; Shatwell et al., 2019; Woolway and Merchant, 2019)
Climate change causes gains and losses in freshwater water level	Global - 1984-2015	Water abstraction, dams / Recent (2002-2016) changes in terrestrial water storage in Australia and Sub-Saharan Africa have been	Water storage increases in the Tibetan Plateau can be more confidently attributed to climate change, since they are corroborated by half-century old ground survey		Global surface water extents have been mapped using Landsat, which showed that from 1984 to 2015, 90,000 km2 of permanent surface water has disappeared globally, while 184,000 km2 of lake surface area has formed elsewhere (Figure ##a). Most of these			Until the influence of climate change on all water fluxes (precipitation, ET, runoff) relevant to specific lake water budgets can be	(1) (Pekel et al., 2016) (2) (Ma et al., 2010) (3) (Rodell et al., 2018)

		attributed to the passage of natural drought and precipitation cycles, not climate change (Rodell et al., 2018). The complexities of lake water storage responses to climate change and the challenges associated with its detection and attribution are reflected in the ongoing debate about the influence of climate change effects on lake water storage (Muller, 2018).	data (Ma et al., 2010), and recent observations from the GRACE satellite mission (Rodell et al., 2018), and because there are minimal irrigated agriculture operations or water diversions which may confound the trend (Rodell et al., 2018).		changes are thought to be attributable to background climate variability, water extractions, and reservoir filling, rather than climate change per se (Pekel et al., 2016).			adequately resolved, the magnitude of climate change effects on global lake water storage will remain highly uncertain, particularly in the presence of interannual climate variability, *low confidence*	
Warming may amplify the trophic state lakes are already in. Eutrophic lakes have been shown to become more productive while nutrient limitation may increase in oligotrophic lakes.	Global - Varies by study. Range 20-50 years	Land-use changes, agriculture	Long-term observations past>40 years, remote sensing data		In nutrient poor lakes prolongation of thermal stratification limits nutrient entrainments via vertical mixing which leads to a reduction in algal biomass (2), while global warming reinforces eutrophication of already eutrophic lakes via oxygen depletion in the sediment near water layers which triggers release of nutrients previously bound in the sediment (3,4).	yes, ecosystem model PCLake (1)	*multivariate statistical analysis, machine learning tools*	*High Agreement* for amplification of eutrophication in eutrophic lakes. *Limited evidence* for climate-change driven enhanced nutrient limitation in deep	1(Mooij et al.); 2 (Kraemer et al.), 3(Adrian et al.), 4(De Senerpont Domis et al.)

						oligotrophic lakes, *medium-high confidence*	
In lakes weather extremes in wind, temperature, precipitation and loss of ice foremost affect the thermal regime with repercussions on water temperature, transparency, oxygen and nutrient dynamics, affecting ecosystem functionality	Global - Past >40 years	Antecedent conditions	In situ monitoring in real time; decadal observations >40 years	Depending on lake type, the severity and timing of the extreme event, and the nature of entrainment from run-off (e.g. DOM) and internal nutrient loads, algal biomass and biodiversity has either declined or increased (1). A once in 250-year flood event in 2009 caused the water column of Lough Feeagh, a large nutrient poor lake in Ireland, to destabilise, followed by reduced primary production (2). The dominant CH4 emission pathway in a shallow productive lake, shifted from gas ebullition to diffusion following high CH4 release from sediments that was driven by colder deep water temperatures during a heatwave (3). Oxygen depletion in the cold deep water body of lakes during heat extremes has forced fish to move upwards into the warm upper water layers where thermal stress and metabolic costs increase. Summer fish kills have been related to summer temperature extremes and near-bottom oxygen depletion (4).		*Agreement is high* that the increase in the number and severity of extreme events can be attributed to climate change*, low-medium confidence*	(1)(Havens et al., 2016) (Kuha et al., 2016) (Kasprzak et al., 2017) (Bergkemper et al., 2018) (Stockwell et al., 2020); (2)(de Eyto et al., 2016); (3)(Bartosiewicz et al., 2016); (4)(Kangur et al., 2016)
Severe floods and droughts are	Global	Antecedent conditions.		Duration of droughts in Mediterranean streams in	mathematical modelling,	*High Agreement*	(1) (Colls et al., 2019)(2)

major threads for river ecosystems		(1) urban development, farming on floodplains, river flow disruptions			NE Iberian Peninsula has been linked to a significant decrease of autotrophic biomass, gross primary production (1) and net primary production in streams (2) . The predicted effects of permafrost thaw include increased inputs of nitrogen, phosphorus and carbon into rivers which are predicted to affect primary and secondary production and hence the species communities (3). Increased forest fire activity in the surrounding catchment of freshwater ecosystems (4) in riparian zones can lead to reduced canopy cover and increased water temperatures, increased stream flow and suspended sediment concentrations. Increased algal levels can hence alter stream food webs (5)and lead to water quality degradation (6).		literature review, observations, boosted regression tree analysis	that the increase in the number and severity of extreme events can be attributed to climate change, *medium-high confidence*	(Zlatanović et al., 2018), (3) (Nilsson et al., 2015), (4)(Abatzoglou and Williams, 2016), (5)(Cooper et al., 2015), (6)(Dahm et al., 2015).
In boreal, coniferous areas changes in forestry practices and climate change have caused an increase in terrestrial derived dissolved organic matter (DOM) transport into rivers and lakes leading to their browning.	Boreal - *Past decades*	Forestry practice, planting of spruce (2); Land-use changes (2). / Non climate related proposed drivers of browning are the strong decline in atmospheric	Long-term observations during past decades (1,4), for review see (2)	Mesocosm experiments (3)	Browning has been shown to drive a shift from auto- to heterotrophic/mixotrophic -based production (2,5) with a subsequent decline in energy transfer efficiency and a reduction of biomass at higher trophic levels (6). Mild browning may accelerate primary production and favour fish production (2014) through input of	An increase in browning by factor 1.3 based on a worst case climate scenario was predicted for 6347 lakes and rivers in the boreal region of Sweden until 2030, which match observed		*Agreement is high* that climate change induced hydrological intensification and greening of the northern hemisphere are major drivers of browning	(1)(de Wit et al., 2016), (2)(Kritzberg et al., 2020), (3) (Urrutia-Cordero et al., 2017), (4) (Creed et al., 2018), (5) (Zwart et al., 2016), (6)(Ellison et al., 2017), (7) (Finstad et al.,

		sulphur deposition since the 1980ties, reducing acidification and by that increasing the solubility and transport of DOC from soils (1,2).			nutrients associated with DOM in nutrient poor lakes(6,8,9) and increase cyanobacteria growth (cyanobacteria better cope with low light intensities(10) and toxin levels (11,12).	trends in the past decades (13).	(Solomon et al., 2015) (de Wit et al., 2016) (Finstad et al., 2016) (Catalán et al., 2016; Creed et al., 2018), {Hayden, 2019, from clear lakes}. *high confidence*	2014), (8)(Thrane et al., 2014), (9) (Seekell et al., 2015) (10) (Huisman et al., 2018) (11)(Hansson et al., 2013) (12) (Urrutia-Cordero et al., 2016), (13) (Weyhenmeyer et al., 2016)
Greenhouse gas emissions from freshwater ecosystems are equivalent to around 20% of global burning fossil fuel CO2 emission	Global - *Past decades*	Eutrophication, agriculture		Fine sediment fraction and organic carbon content were important drivers of methane production and potential methane oxidation in rivers- based on field/laboratory studies (1); CH4 ebullition due to temperature induced increase in sediment CH4 production will increase in freshwater ecosystem; literature data combined with mesocosm experiments (2).	CO2 and CH4 emissions from freshwater ecosystems are likely to increase due to the imbalance between losses and gains of CO2 by photosynthesis and respiration, enhanced emissions from exposed sediments during droughts (3,4), enhanced CH4 ebullition of seasonally hypoxic lakes (2,5,6,7,8), increased matter transport from land to water (particularly permafrost thaw) (6) are key mechanisms which contribute to rising GHG emissions from freshwater ecosystems to the atmosphere.		Uncertainty primarily stems from the large site specific heterogeneity of CO2 and CH4 dynamics (6), seasonality of their sediment-water–air fluxes (6,9), the exclusion of ponds and the winter season in global carbon flux estimates (6,9), procedures of upscaling (6) and measuring techniques (5), *medium to low confidence*	(1)(Bodmer et al., 2020), (2) (Aben et al., 2017), (3) (Marcé et al., 2019); (4) (Keller et al., 2020); (5) (Sanches et al., 2019); (6)(DelSontro et al., 2018); (7) (Beaulieu et al., 2019); (8)(Bartosiewicz et al., 2019), (9) (Denfeld et al., 2018)
Climate change induced warming	North America,	Antecedent conditions	Lowland rivers have been				*Robust evidence,*	(1) (Piccolroaz et al., 2018) (2)

leads to shifts in thermal regime of rivers and streams; lowland rivers show a stronger thermal response than high-altitude, cold-water receiving streams	Europe - Past decades		observed to be extremely sensitive to heatwaves while high-altitude snow-fed rivers and regulated rivers receiving cold water from higher altitude showed a damped thermal response (1); small mountain streams do not warm linearly with increasing air temperature because of strong local temperature gradients associated with topographic controls (2)	*high confidence*	(Isaak et al., 2016)
Loss of biodiversity in streams can be directly attributed to climate change through increased water temperatures, hydrological changes such as increased peak discharges, flow alteration and droughts	Global - Past decades	Antecedent conditions	Observed long-term trends in stream macroinvertebrates have shown that changes in species composition and community structure can be attributed to climate change triggered by hydro climatic changes (1,2). In the Mediterranean climate change may increase the occurrence of droughts and reduce small floods needed to guarantee habitat	*high agreement, very high confidence*	(1)(Daufresne et al., 2007), (2)(Chessman, 2009), (3) (Death et al., 2015), (4)(Jaric et al., 2019), (5)(Mouthon and Daufresne, 2015).

			diversity (3) particularly threatening fish species of small body size, small range size and low dispersal abilities (4). Heat waves have shown to alter the density, species richness and structure of mollusc communities, favouring more resilient species with a slow pace of recovery (5).		
Climate change is causing range shifts of freshwater fish	North America - *Past decades*	Antecedent conditions	Systematic shifts towards higher elevation and upstream were found for 32 stream fish species in France following geographic variation in climate change (1). Stream fish are currently responding to recent climate warming at a greater rate than many terrestrial organisms, although not as much as needed to cope with future climate modifications (1). Range contractions have been found for Bull trout	*high agreement, high confidence*	(1) (Comte and Grenouillet, 2013), (2) (Isaak et al., 2010), (3) (Eby et al., 2014).

			(Salvelinus confluentus) (2,3)						
Whole biome shifts have occurred. Boreal forests have shifted into arctic tundra, treeline has shifted upward into alpine tundra, temperate deciduous shrubs and forests upwards into conifer forest, xx	Global	Mixed. add detail							
Woody encroachment into open (grassland, desert) systems has occurred globally, with climate change as one of the primary drivers	Global	Yes - loss of browsing herbivores; fire suppression. Reviews of long term experiments demonstrate impacts (1) / yes - (2)	yes - emergence of grasslands after CO2 came down below ~500ppm (3) yes -Long-term fire and grazing trials show woody encroachment occurs even when land use is held constant or accounted for indicating a global driver. (5)	Experiments manipulating CO2 benefit woody plants (4)		yes - indicating co2 driven increase in woody cover (6)	Yes - consistent encroachment across all savannas (8).	*Robust evidence* that climate change is one of the primary drivers, but LUC also primary driver. *Robust evidence* (lots of studies) but *medium agreement* on climate-change attribution because of complex drivers. *medium confidence*	(1)(Smit and Velthof; Bond and Midgley, 2012; Bakker et al., 2016) (3) (Ehleringer et al., 2002) (Beerling and Osborne, 2006)(4) (Polley et al., 1997; Bond and Midgley, 2000; Kgope et al., 2010) (Hoffmann and Jackson) (Quirk et al., 2019)(5) (Buitenwerf et al., 2012; Venter et al., 2018; Zhang, 2019) (6) (Scheiter and Higgins, 2009; Moncrieff et al., 2014; Scheiter et al., 2018) (8) (Stevens et al., 2017)

Widespread greening and shrubbification of tundra	High artic and mountain tundra - data starting in 1900		yes - satellite and long term repeat photos (5)	yes - network of warming experiments link warming to increases in shrub, grass and sedge species (4)			Yes - widespread shrubbification (8).	*robust evidence, high agreement, high confidence*	(4) (Elmendorf et al., 2012a; Elmendorf et al., 2012b; Elmendorf et al., 2015; Bjorkman et al., 2018; Bjorkman et al., 2019; Myers-Smith et al., 2019) (5) (Tape et al., 2006; Phoenix and Bjerke, 2016) (8) (Myers-Smith et al., 2011)
Tropical forests	Tropical region								
Drought and warming induced diversity shifts in Mediterranean type ecosystems	Mediterranean ecosystems	Insect outbreaks associated with drought (1); loss of fish species (Jaric et al., 2019) (9)	yes - Field surveys of long term monitoring show reduced diversity or shift in functional due to increasing prevalence of extreme hot and dry weather often the post-fire regeneration phase(5)				yes - increase in extreme droughts in regions (8)	*medium evidence* changes are mediated by an increase in extreme droughts. Changes are not always direct but interact through altering the fire regime and post-fire recovery	(1) (McIntyre et al., 2015; Fettig et al., 2019) (5) (McIntyre et al., 2015; Slingsby et al., 2017; Harrison et al., 2018 2018; Smithers et al., 2018; Stephenson et al., 2018; Fettig et al., 2019) (8) (AghaKouchak et al., 2014; Robeson; Otto et al., 2018; Sousa et al., 2018), (9) (Jaric et al., 2019)
Deserts									
Med shrublands shifting to grasslands	Mediterranean ecosystems, arid shrublands	Human driven fragmentation and nitrogen deposition benefits grasses (1)	Long-term						(1) (Lambrinos, 2006; Fenn et al., 2011)

Terrestrial carbon stocks				*varies by region and ecosystem type*	(5) (Jacobsen and Pratt, 2018; Syphard et al., 2019 2019; Young et al., 2019) see section {2.4.4.4}
Droughts associated with El Nino lead to an increase of anthropogenic fire in drained tropical peatlands	Southeast Asia - Past decades		Long term monitoring and remote sensing show grass invasions (5)	*high confidence*	(Herawati and Santoso, 2011; Page and Hooijer, 2016)

Table SM2.2: Assessment of uncertainties associated with key statements on Projected Impacts. See SM2.1 caption for descriptions of lines of evidence. Where evidence is provided in main text, only the relevant section is noted.

Key statement	**Geographic region and *Period***	**Non-climatic Drivers: Land Use and Land Cover Change (LULCC)1 or Other Changes**	**Study design**		**Independent evidence; paleo data and *long term observations***	**Levels of evidence, agreement and confidence for attribution**	**SOD sections**	**References and results**
			Numbers of studies and/or numbers of different models used to generate projected impacts	**Level of agreement among studies and/or model outputs**				
Continued climate change under high emissions scenarios could increase future wildfire frequency on one-third to two-thirds of global land by 2100 and decrease fire frequency on one-fifth of global land, with a net global fire frequency increase of ~30% per century						*medium confidence*	{2.4.4.2; 2.5.5.2}	
Increased wildfire, combined with erosion due to deforestation, could degrade water supplies						*medium confidence*	{2.4.4.2; 2.5.5.2}	
For ecosystems with historically low fire frequencies, particularly tropical rainforests, projected increases of drought under continued climate						*medium confidence*	{2.4.4.2; 2.5.5.2}	

change increase risks of fire, which could cause biome shifts, e.g., potential conversion of over half the area of Amazon rainforest to grassland.							
Terrestrial ecosystems protect globally critical stocks of carbon and provide an essential service of sequestration of carbon from the atmosphere but are at risk of carbon losses from deforestation and climate change						*high confidence*	{2.4.4.4; 2.5.1}
Percentages of species projected to suffer extinction vary from zero to 64% with a threshold for extinction of >80% of the species' climate space disappeared. With a threshold for extinction of >50% climatic range lost, under 3.2 °C warming, 49% of insects, 44% of plants, and 26% of vertebrates are projected to be at risk of extinction. At 2°C, this falls to 18% of insects, 16% of plants, and 8% of vertebrates and at 1.5°C, to 6% of insects, 8% of plants, and 4% of vertebrates.	Global	yes for some studies	178 studies. Each study is of a variable number of species, ranging from a few to >100,000 species. Modeling approaches include a range of biological models (SDMs as well as process-based models) and multiple GCMs and warming scenarios.	medium to high agreement for same species or dataset, low agreement across studies of multiple species	Ever-increasing evidence of current impacts of climate change on wild species in turn gives us higher confidence in future projections of biodiversity changes that are based upon known relationships between species and climate.	Differences in estimates of extinction risk stem from differing assumptions of thresholds for extinction risk, differing geographic regions and taxonomic groups, as well as differing modeling approaches and emissions scenarios, Confidence highly dependent upon statement of range of species' extinctions	{2.5.1.3.3,; 2.5.4}
Climate change induced warming leads to shifts in thermal regime of lakes	Global - Representative concentration pathway 8.5			high			{2.3.3.6; 2.5.1.3.2; 2.5.3.6.2}

Substantial changes in vegetation structure and ecosystem processes are expected to for already relatively small temperature increases (<2°C above pre-industrial), in particular in cold (boreal, tundra) regions, as well as in dry regions [*high confidence*]. Land-use change will exacerbate projected impacts on ecosystems and will alter ecosystem function and vegetation cover in addition to climate change. Models agree on impacts increasing rapidly with level of global mean temperature change; models also agree that these impacts will be visible the earliest in boreal/tundra regions, as well as in dry areas. Nonetheless there are discrepancies regarding the regional patterns of impacts, not only for climate change but also for land-use change.	Global, Tropical boreal - 2100, climate/CO_2 as in RCP 2.6, 4.5, 8.5	Yes for some experiments, from LUH/CMIP5 N/A	Factorial model experiment (HadGEM2-ESM	Greening and browning observed in satellite remote sensing studies, and attributed to LUC and climate change/CO_2. their relative impacts vary widely over the globe -- see E:G: Piao et al., 2016		Projected changes at the biome level {2.5.2.2} See also SM2.3 and Figure 2.9	(Davies-Barnard et al., 2015) Forest fraction change: global & boreal--increasing with CC/CO_2, most strongly in RCP8.5; tropical -- impacts are small, slight decline in RCP2.6; global/boral/tropical -- decline in response to LUC for 2.6 and 8.5, increase in 4.5.
	Global - 2100, climate/CO_2 as in RCP 2.6, 4.5, 6.0	Yes, for some experiments, from LUH/CMIP5 N/A	DGVM (LPJ) with multiple CMIP5 ESM climates, caclulate "gamma metric" which expresses strenght of change in biome shifts and bieogeochemical cycles/ecosystem services				(Ostberg et al., 2013; Ostberg et al., 2018) For RCP2.6, still >20% of land surface notably impacted by climate change (mostly tundra, boreal regions, but also dry grasslands/deserts). Increasing to >30% (RCP 4.5) and >40% (6.0) of the land surface, and increasingly including now also tropical seasonal forests expanding into tropical forests and into savannas. In a RCP8.5 world, >50% of land sirface affected by climate change alone. LUC substantially enhances the land surface transformation in addition to climate change but areas of largest climate change impacts and largest LUC impacts do not necessarily overlap in many places.
	Global - 2100, climate/CO_2 as in RCP 2.6, 4.5, 6, 8.5	No N/A	Seven global vegetation models, driven by ISIMIP climate projections			Projected changes at the biome level {2.5.2.2} See also SM2.3 and Figure 2.9	(Warszawski et al., 2013) At 2oC warming above 1980-2010 levels, 5-19% of land surface at risk of severe change; extend of regions at risk more or less

	Global - 2100, climate/CO_2 as in RCP8.5	No N/A	DGVM LPJ-GUESS & MPI-ESM climate				doubles between 2oC and 3oC mean global warming, at 4oC warming ca. 35% of land surface projected to be notably impacted. Vegetation models to some extend disagree on regional patterns of impacts are largest, but agreement that high northern latitudes will be strongly affected. (Wårlind et al., 2014) Shifts in vegetation composition in many regions, for instance wood vegetation increase in tundra, larger component of evergreens in mediterranean regions, more drought-tolerant woody vegetation in savanna.
Novel abiotic conditions are expected to also result in no-analogue vegetation composition [*medium confidence*]	Global - *ca. 2050, RCP6.0*	No N/A	Uses projections of abiotic conditions (R, precip., N deposition) plus human population density. Relative to an estimated present-day baseline. Measure: minimum dissimilarity scores. Climate: ensemble of 12ESMs		*medium confidence that novel abiotic conditions will also be seen in novel ecosystems, but low confidence as to where these will emerge.*	Projected changes at the biome level {2.5.2.2} See also SM2.3 and Figure 2.9	(Radeloff et al., 2015) T (and N deposition) largest driver of novelty; large degree of novelty in tropics and subtropics because temperatures reach levels that haven't been seen in the recent past; despite of overproportional warming level of novelty in high latitudes in some regions smaller because these temperatures also occur elsewhere globally, so not novel.
	Global - *2100, SRES B1, A2*	No N/A	Vegetation model JeDi, identify distribution of simulated no-analogue		*medium confidence that novel abiotic conditions will also be*	Projected changes at the biome level {2.5.2.2} See also SM2.3 and Figure 2.9	(Reu et al., 2014) Find no-analogue climate in (sub)tropical regions, mostly of the northern hemisphere and non-analogue vegetation in

			vegetation and compare to no-analogue climate. Does not consider CO_2 impacting photosynthesis. Climate analogues obtained from seven GCMs/AR4.		*seen in novel ecosystems, but low confidence as to where these will emerge.*		Finland and western Siberia. Effects stronger in A2.
At least part of what is now humid tropical forest is projected to shift increasingly towards vegetation with traits that correspond to drier and hotter climate [*high confidence*]	Tropical/Ghana - *NA*	No N/A	Species functional traits plus vegetation census data (plots) along a rainfall gradient; calculate community-level weighted mean for each trait and plots, CWM is indicator of mean canopy properties. Explore empirical relationship with soil water deficit.			Risk to tropical forest {2.5.2.6}	(Aguirre-Gutiérrez et al., 2019) Drier tropical forests increased their deciduous species abundance and generally changed more functionally than forests growing in wetter conditions, suggesting an enhanced ability to adapt ecologically to a drying environment.
	Tropical/Amazon - *NA*	No N/A	Calculate exposure as meteorological drought, using the standardized precipitation index (SPI) and the maximum cumulative water deficit (MCWD) from 1981 to 2016 & assess changes in enhanced vegetation index				(Anderson et al., 2018; Bartlett et al., 2019) Minimum and maximum AEVI indicate that droughts tend to increase the variance of the photosynthetic capacity of Amazonian forests; intensity of negative AEVI increased with time (2005-2016), forest may become more vulnerable to droughts.

			anomalies (AEVI, from MODIS).			
	Tropical - *Stylised droughts; 400 and 800 ppm* CO_2	No N/A	Empirical model, linking photosynthesis and stomatal conductance and other drought-related traits to soil water content. Parameterised with field data. Evolutionary stable state analysis to identify shifts in competitively optimal hydraulic traits.			(Anderson et al., 2018) Drought impacted competition more than CO_2, with elevated CO_2 reducing but not reversing drought-induced shifts towards more tolerant strategies --> shifts towards drought adapted vegetation.
	Tropical, global - *NA*	No N/A	Reviews, published literature on observed drought-impacts.			(Bonai et al., 2016) Wide range of responses, seen in e.g. mortality, growth, LAI, carbon fluxes, shifts in traits. While responses are variable seem to support projected shifts towards initial mortality of trees and then shift to more xeric vegetation. Large uncertainties w.r.t. changes in phenology and carbon fluxes.
	Tropical/Amazon - NA	No N/A	Forest cencus data in humid forests, chronosequences after fire, compared to surrounding unburned plots.			(da Silva et al., 2018) Reduced forest biomass and enhanced post-fire mortality that might last years/decades after fire.
	Tropical/Central/South America - *NA*	No N/A	Review, published literature on observed			(Stan and Sanchez-Azofeifa, 2019) Climate along a latitudinal gradient

			climate-impacts in tropical dry forest.					indicates drought tolerance.
	Tropical/Amazon - *2050, climate/CO_2 as in RCPs2.6, 4.5, 8.5*	No N/A	Review, published literature of climate change and land-use chage impacts & simulations with vegetation model CPTEC-PVM2 with nine CMIP5 GCMs					(Nobre et al., 2016) 4°C warming or deforestation exceeding 40% of the forest area estimated as tipping point towards "savannisation".
	Tropical/Latin America - *2100, climate/CO_2 as in RCP2.6 and 8.5*	yes, in some experiments N/A	Projections with DGVM LPJmL, driven by five ISIMIP climate projections. Land-use change from CLUE, combined with SSPs.					(Boit et al., 2016) Across all scenarios 5–6% of the total area will undergo biome shifts that can be attributed to climate change until 2099, even in the RCP8.5. Changes clearly dominated by land.use change. CO_2 fertilisation helps to buffer negative climate change impacts.
	Tropical - *2100, climate/CO_2 as in SRES A2*	No N/A	DGVM Moses-Trifid & 22 GCM (from AR4), emulated with pattern-scaler model IMOGEN	Agreement that forest gain biomass, but very large variability in projected tropical forest biomass, depending on which GCM used, despite of only using a single emission scenario				(Huntingford et al., 2013) Agreement that forest gain biomass, but very large variability in projected tropical forest biomass, depending on which GCM used, despite of only using a single emission scenario. Towards end of 21st century peak in biomass-gain and downturn. Only one of all 22 simulations forest projected to loose biomass, and this only in the South American tropics.
	Tropical/Amazon - *2100, climate/CO_2 as*	No N/A	Trifid + HadCM3					(Boulton et al., 2017) Little change in Amazon forest

	in SRES A1B, RCP 2.6, RCP 8.5						cover for A1B and RCP 2.6, decline in some of the ensemble runs under RCP 8.5. Impacts get stronger in time periods beyond 2100 ('comitted')
On different continents, and from mesic to dry savannah sub-regions, the relative importance of climate, fire and other factors in shaping savannah vegetation and distribution varies, which makes projections of the change of the biome's extend challenging. Due to the continued strong effect of CO_2 on tree to grass ratio in future, models suggest both a loss of savannah extend and conversion into dry forest and an expansion of savannah-type vegetation into arid grasslands.	Savanna - *2070, RCP4.5*	No N/A	Thornley transport resistance statistical distribution model & three versions of aDGVM + MPI ESM-LR			Risk to savannas {2.5.2.5}	(Moncrieff et al., 2016) 2070: DVM project reduced extent of savannah at boundary with forests, while the TTR-SDM projects savannah decrease at boundary with grassland. TTR does not include CO_2 impacts.
	Savanna/Africa - *2100, SRES A1B*	No N/A	aDGVM + climate from ECHAM5				(Higgins and Scheiter, 2012) (woody) C3 vegetation increases in from dominating less then 5% of study area surface in 2020 to ca. 20% at end of century.
Models of vegetation response to climate project that the observed increases in shrub dominance and in boreal forest encroachment driven by recent warming are to accelerate in coming decades, especially under the higher greenhouse gas emissions scenarios, leading to a shrinking of the area of tundra globally	Tundra - *2070, RCP 4.5*	no yes?	SDMs, 116 vascular plants, based on plot observation data -- presumably no CO_2 impact on plants			Risk to tundra and boreal forest {2.5.2.9}	(Mod and Luoto, 2016) Abundance of woody plants will expand, decreasing predicted species richness, amplifying species turnover and increasing the local extinction risk for ambient vegetation
	Tundra - *2050 and 2070, climate as in RCPs 2.6 - 8.5*	no	statistical vegetation model CSCS + enesmble 33 GCMs, unclear if model accounts for CO_2				(Gang et al., 2017) Area of tundra declines in basically all future projections, highest impact in high emission scenarios.
	Tundra - *2074; 0, 2.5, 5, 8°C warming compared to 1994*	No N/A	vegetation model NUCOM-tundra + 16 different climate scenarios; unclear if model accounts for CO_2				(van der Kolk et al., 2016) Abrupt permafrost thaw initiating thaw pond formation led to complete domination of graminoids: shrub growth limited by very wet soil conditions and low nutrient

							supply/graminoids can grow in wide range of soil moistures & access nutrients in deeper soil layers.
Boreal tree species are expected to move northwards (or in mountain regions: upwards) into regions dominated by tundra, unless constrained by edaphic features, and temperate species are projected to grow in regions currently occupied by southern boreal forest. In both biomes, deciduous trees are simulated to increasingly grow in regions currently dominated by conifers.	Boreal forest/Siberia - *2100, climate/CO_2 as in RCP8.5*	No N/A	DGVM LPJ-GUESS & ECHAM5.5-HAM2 climate				(Arneth et al., 2016) Areas dominated by löarch shift northwards, overall area of larch-dominateed forest declines. Expansion of deciduous vegetation at southern edge.
	Global/boreal regions (45-80oN) - *2100, SRES A1B and climate stabilisation scenario*	No N/A	HadCM3C				Falloon et al., 2012 Increases in shrub and needleleaf trees at high latitudes.
While the future of the global land carbon sink is highly iuncertain, possibly enhanced carbon losses from terrestrial systems further will limit the available carbon budget for global warming staying below 1.5oC [*high confidence*]	Permafrost region - *2300, Stabilisation for RCP4.5 and 8.5 (no changes after 2100). No CO_2 impacts included.*	No N/A	Empirical relationship to determine permafrost area from MAAT. Develop relationships between mean annual air T and nine CMIP5 GCMs. Estimate future air temperatures by increasing historical air temperatures by the global mean warming, multiplied by an Arctic amplification factor, using CMIP5 models.			Risk to terrestrial carbon {2.5.3.4}	(Chadburn et al., 2017) Simulations under two future climate scenarios show near-surface permafrost loss per degree of warming between 1.1 and 1.2 million km^2 (in the new model version). If the climate is stabilized at 2°C estimate are that the permafrost area would eventually be reduced by over 40%. Stabilizing at 1.5°C rather than 2°C (above PI) would save approximately 2 million km^2 of permafrost.
	Permafrost region - *2100, 1.5o and 2o warming trajectories, incl. 1.5oC with overshoot; include CO_2*	No N/A	Ecosystem model Jules + Climate change emulator IMOGEN				(Comyn-Platt et al., 2018) By 2100, the model ensemble estimates a median 138 Mha loss of permafrost area at 3 m depth for the 1.5°C asymptote pathway, and a

								median 239 Mha loss for the 2.0°C pathway. Simulates an additional 40.0–46.3, 45.6–51.2 and 61.9–72.0 GtC of pre-industrial permafrost carbon that is no longer perennially frozen, relative to 2015, for the three temperature scenarios. Between 20 and 30% of this newly thermally active carbon released to the atmosphere.
	Permafrost region - *2300, RCP 8.5 & 4.5*	No N/A	Inventory models + CCSM4 climate					(Turetsky et al., 2020) Emissions across 2.5 million km^2 of abrupt thaw; under RCP8.5 area of thaw threefold larger than with only gradiual thaw. Emissions of ca. 80 +- 19PgC by 2300, results suggest that abrupt thaw carbon losses are equivalent to approximately 40% of the mean net emissions attributed to gradual thaw.
	Permafrost region - *2100, climate and CO_2 as in RCP4.5 and 8.5*	No N/A	Eight ecosystem models	Large between model spread, but agreement in direction of model response w.r.t. loss of area; four of five models that simulate C-response show increase in vegetation C and all five show				(McGuire et al., 2018) Projected losses of permafrost between 3 - 5 million km2 for the RCP4.5 6 -16 million km2 for RCP8.5. RCP4.5: cum. change in soil carbon 66 Pg C loss - 70 Pg C gain. RCP8.5: losses in soil carbon, 74 - 652 Pg C. For RCP4.5, gains in vegetation carbon were largely responsible for the overall projected net gains in ecosystem carbon (8 to 244Pg C gains). For RCP8.5 projection, gains in vegetation carbon were

				decrease in soil C (in RCP 8.5) but with large spread between models.				not great enough to compensate for the losses of carbon projected by four of five models (641Pg C loss to 167Pg C gain).
	N America arctic tundra - *2100, RCP8.5 climate and* CO_2	No N/A	ecosystem model Ecosys + downscaled CMIP5 ensemble climate projections					(Mekonnen et al., 2018) Between 1982 and 2100 averaged increases in relative dominance of woody versus non-woody plants; increased ecosystem annual NPP (244 g C m−2) offsets increases in annual Rh (139 g C m−2), resulting in an increasing net carbon sink over the 21st century.
	Peatlands, Amazon (Peru) - *2100, climate/*CO_2 *as in RCP2.6, 4.5 and 8.5*	No N/A	Peatland ecosystem model P-TEM + CCSM3 climate					(Wang et al., 2018) Under warmer (and presumably wetter) conditions over the 21st century, SOC accumulation rate in the study region slows down to 7.9 (4.3–12.2) g·C·m−2·y−1 (from the current rate of16.1 (9.1–23.7) g·C·m−2·y−1); region may turn into a carbon source (−53.3 (−66.8 to−41.2) g·C·m−2·y−1), depending on the level of warming.
	Peatlands, northern hemisphere - *2100, RCP/*CO_2 *as in 2.6, 6, 8.5*	No N/A	ORCHIDEE-peat + IPSL-CM5A-LR GCM and GFDL-ESM2M					(Qiu et al., 2020) Current carbon this sink will roughly double in the future under both RCP2.6 and RCP6.0, whereas the total northern peatlands will be either a source of CO_2 (IPSL-CM5A-LR) or near neutral (GFDL-ESM2M) by the end of the century under RCP8.5.

	Global - *2100, no climate change*	Yes (drainage)	Empirical, based on literature values for peatland area and emission factors.					(Leifeld et al., 2019) By 2100, peatland conversion in tropical regions might increase to 36.3 million ha. Cumulative emissions from drained sites reached 80 ± 20 PgCO_2e in 2015 and will add up to 249 ± 38 Pg by 2100. At the same time, the number of intact sites accumulating peat will decline.
	Tropical peatland/Malaysia, Indonesia	Yes (peat swamp/oil plantation)	Empirical, upscaled measurements					(Cooper et al., 2020) Measurements of GHGs emitted during the conversion from peat swamp forest to oil palmplantation, accounting for CH4and N2O as well as CO_2. Emissions factors for converted peat swamp forest is in the range 70–117 t CO_2eq ha−1yr−1, with $CO_2$and N2O responsible for ca. 60 and ca. 40% of this value, respectively. These GHG emissions suggest that conversion of Southeast Asian peatswamp forest is contributing between 16.6 and 27.9% of combined total nationalGHG emissions from Malaysia and Indonesia.
	Tropica peatland - *none*	Yes	Review paper					(Page and Baird, 2016)
	Tropical- *2100, climate/CO₂ as in SRES A2*	No N/A	DGVM Moses-Trifid & 22 GCM (from AR4), emulated with pattern-scaler model IMOGEN	Agreement that forest gain biomass, but very large variability in projected tropical forest				(Huntingford et al., 2013) Agreement that forest gain biomass, but very large variability in projected tropical forest biomass, depending on which GCM used, despite of only using a single emission scenario. Towards end of 21st

				biomass, depending on which GCM used, despite of only using a single emission scenario				century peak in biomass-gain and downturn. Only one of all 22 simulations forest projected to loose biomass, and this only in the South American tropics.
	Global - *2100, SRES A2 climate and* CO_2	No N/A	Jules,. Adjusted for T-acclimation of photosynthesis + emulated climate from 22 AR4 GCMs					(Mercado et al., 2018) Results suggest that thermal acclimation of photosyntheticcapacity makes tropical and temperate C less vulnerable to warming, but reduces the warming-induced C uptake in the boreal region under elevated CO_2.
Cascading trophic effects triggered by top predators or the largest herbivores propagate through food webs and reverberate through to the functioning of whole ecosystems, altering notably productivity, carbon and nutrient turnover and net carbon storage [*medium confidence*]	Western North America - *none*	No N/A	Data on population densities of a primary and secondary consumers across a climatic gradient; satellite-based maps of plant productivity + estimates of animal abundance and foraging area				Risk to terrestrial carbon {2.5.3.4}	(Stoner et al., 2018) Data indicate strong, positive association between plant productivity and mountain lion density 8via impacts on mule deer). Droughts and longer-term climate changes reduce the suitability of marginal habitats--> consumer home ranges will expand in order for individuals to meet basic nutritional requirements. These changes portend decreases in the abundance of large-bodied, wide-ranging wildlife through climatically-driven reductions in carrying capacity.
	Africa savanna - *none*	No N/A	LPJ-GUESS + grazing module					(Pachzelt et al., 2015) The grazer–vegetation model predicted substantial impacts on grass biomass (mostly increases), total

						veg carbon was medium affected (c. 10%) and burned area (increase), particularly in areas with high grazer densities.
	Africa, lowland primary forest - *none*	No N/A	Ecosystem model ED + elephant disturbance			(Berzaghi et al., 2019) Elephants: reduction of forest stem density --> changes in the competition for light, water and space among trees --> emergence of fewer and larger trees with higher wood density --> increases the long-term equilibrium of aboveground biomass, reduces the forest NPP (trade-off between productivity and wood density). Typical density of 0.5 to 1 animals per km² --> elephant disturbances increase aboveground biomass by 26–60 t ha−1; Extinction of forest elephants would --> 7% decrease in the aboveground biomass in central African rainforests.

Table SM2.3: Projected vulnerabilities and risks of ecosystems to biome shifts from spatial analyses of vegetation biogeography, in order by type of analysis, analysis area, and projected change in temperature. Data underlying Figure 2.9

Area	ΔT (ºC)	Emissions scenario	Biome change, fraction of area (%)	Number of biomes	Number of GCMs	Biome shift criterion	Spatial resolution (km)	Vegetation model	Reference
Dynamic global vegetation models									
World	1	RCP2.6	~4	5–14	3	risk >0.3	~50	Hybrid, JeDi, JULES, LPJmL, ORCHIDEE, SGVM, VISIT	(Warszawski et al., 2013)

World	1.5	1.5º C	~5	2	16	P >0.80	~150	LPJ	(Scholze et al., 2006)
World	≤2	B1	7	8	12	|change| >30%	~50	LPJ	(Park et al., 2015)
World	2.4	B1	10	13	3	confidence >0.8	50	MC1	(Gonzalez et al., 2010b)
World	2.5	+2–3º C	~5	2	16	P >0.80	~150	LPJ	(Scholze et al., 2006)
World	2	RCP4.5	13	5–14	3	risk >0.3	~50	Hybrid, JeDi, JULES, LPJmL, ORCHIDEE, SGVM, VISIT	(Warszawski et al., 2013)
World	3	RCP6.0	28	5–14	3	risk >0.3	~50	Hybrid, JeDi, JULES, LPJmL, ORCHIDEE, SGVM, VISIT	(Warszawski et al., 2013)
World	2.5–3.5	A1B	10	8	18	|change| >30%	~50	LPJ	(Park et al., 2015)
World	3.4	A1B	13	13	3	confidence >0.8	50	MC1	(Gonzalez et al., 2010b)
World	3.5	3.5ºC	~5	2	16	P >0.80	~150	LPJ	(Scholze et al., 2006)
World	≥3.5	A2	13	8	18	|change| >30%	~50	LPJ	(Park et al., 2015)
World	4	A2	16	13	3	confidence >0.8	50	MC1	(Gonzalez et al., 2010b)
World	3.1–4.7	historical climate and B1, A1B, A2	12	13	3	confidence >0.8	50	MC1	(Gonzalez et al., 2010b)
World	~3.5–5.5	A1B	~10–30	5	8	range of GCMs	~280	CLM	(Alo and Wang, 2008)
World	4	RCP8.5	35	5–14	3	risk >0.3	~50	Hybrid, JeDi, JULES, LPJmL, ORCHIDEE, SGVM, VISIT	(Warszawski et al., 2013)
World	4.6	A1FI	~10	2	1	|change| >50%	~250–375	HyLand	(Sitch et al., 2008)

World	4.6	A1FI	~20	2	1	|change| >50%	~250–375	LPJ	(Sitch et al., 2008)
World	4.6	A1FI	~10	2	1	|change| >50%	~250 x 375	ORCHIDEE	(Sitch et al., 2008)
World	4.6	A1FI	~15	2	1	|change| >50%	~250 x 375	TRIFFID	(Sitch et al., 2008)
Africa	-	A1B	~26	5	1	change in one GCM	~30	aDGVM	(Scheiter and Higgins, 2009)
Asia - Qinghai-Tibetan Plateau	1.5	RCP4.5	55	19	1	change in one GCM	~50	LPJ	{Gao, 2016, Climate change and}
Asia - Qinghai-Tibetan Plateau	4.2	RCP8.5	70	19	1	change in one GCM	~50	LPJ	{Gao, 2016, Climate change and}
Asia - Siberia	2	+2.6ºC after 130 y	~5	2	-	|change| >50% of area	372 sites	FAREAST	(Shuman et al., 2011)
Europe	2.9–4.9	A2	~30–40	13	2	change in one GCM	~12 x 18	LPJ-GUESS	(Hickler et al., 2012)
South America - Amazon	2	A2	~30	2	1	change in one GCM	~250 x 375	HadCM3LC	(Jones et al., 2009)
South America - Amazon	~3	RCP4.5	~50	15	1	change in one GCM	~190 x 125	Inland	(Lyra et al., 2016)
South America - Amazon	~6	RCP8.5	~80	15	1	change in one GCM	~190 x 125	Inland	(Lyra et al., 2016)
Equilibrium models									
World	1	RCP2.6	10	14	10	vulnerability index >0.7	~10	vulnerability index	(Li et al., 2018a)
World	1.8	RCP4.5	12	14	10	vulnerability index >0.7	~10	vulnerability index	(Li et al., 2018a)
World	3.7	RCP8.5	15	14	10	vulnerability index >0.7	~10	vulnerability index	(Li et al., 2018a)
World	2–4	A1B	37	5	10	average of GCMs	~100	EVE	(Bergengren et al., 2011)
Africa - South		A1B	50	7	1	change in one GCM	~20	aDGVM	(Moncrieff et al., 2015)

Africa - West		A2	~50	5	17	weighted average of GCMs	~10	GAM	(Heubes et al., 2011)
Asia - India	3	+3ºC, +15% precipitation	~25	7	1	change in one scenario	1	Minimum distance supervised classification	(Chakraborty et al., 2013)
Asia - India		RCP4.5	14	11	19	agreement >0.75	~10	RF	(Rasquinha and Sankaran, 2016)
Asia - India		RCP8.5	18	11	17	agreement >0.75	~10	RF	(Rasquinha and Sankaran, 2016)
North America - Northwest		Historical climate and A2	50–57	33	2	change in one GCM	~1	Rehfeldt	(Langdon and Lawler, 2015)
North America - Yukon	3.9–6.9	A2	50	25	5	two projected changes in biome	~18	SNAP-EWHALE	(Rowland et al., 2016)
South America		A2	~5–40	13	14	confidence >0.75	~170	CPTEC-PVM2	(Lapola et al., 2009)
Tropical forests	2	+2ºC	<5	2	16	P >0.80	~100	MWCD	(Zelazowski et al., 2011)
Tropical forests	4	+4ºC	~5	2	16	P >0.80	~100	MWCD	(Zelazowski et al., 2011)
Combined climate change and land use change									
World	1	RCP2.6	22	9		risk >0.3	~50	LPJmL	(Ostberg et al., 2018)
World	1.8	RCP4.5	34	9		risk >0.3	~50	LPJmL	(Ostberg et al., 2018)
World	2.2	RCP6.0	41	9		risk >0.3	~50	LPJmL	(Ostberg et al., 2018)
World	3.7	RCP8.5	54	9		risk >0.3	~50	LPJmL	(Ostberg et al., 2018)
World	3.1–4.7	historical climate and B1, A1B, A2	48	13		confidence >0.8	48	MC1	(Eigenbrod et al., 2015)
Latin America	1	RCP2.6	8–14	9	5	average of GCMs	~50	LPJmL	(Boit et al., 2016)
Latin America	3.7	RCP8.5	10–15	9	5	average of GCMs	~50	LPJmL	(Boit et al., 2016)

Table SM2.4: Biome Change. Data underlying Figure Box 2.1.1

Full reference	Year	Continent	Country	Ecosystem Change	Start. Year	End.Year
Axelsson, C. R., & Hanan, N. P. (2018). Rates of woody encroachment in African savannas reflect water constraints and fire disturbance. Journal of biogeography, 45(6), 1209-1218.	2018	Africa	Angola	Shrub/woodland cover gain	2002	2016
Axelsson, C. R., & Hanan, N. P. (2018). Rates of woody encroachment in African savannas reflect water constraints and fire disturbance. Journal of biogeography, 45(6), 1209-1218.	2018	Africa	Angola	Shrub/woodland cover gain	2002	2016
Axelsson, C. R., & Hanan, N. P. (2018). Rates of woody encroachment in African savannas reflect water constraints and fire disturbance. Journal of biogeography, 45(6), 1209-1218.	2018	Africa	Botswana	Shrub/woodland cover gain	2002	2016
Axelsson, C. R., & Hanan, N. P. (2018). Rates of woody encroachment in African savannas reflect water constraints and fire disturbance. Journal of biogeography, 45(6), 1209-1218.	2018	Africa	Botswana	Shrub/woodland cover gain	2002	2016
Axelsson, C. R., & Hanan, N. P. (2018). Rates of woody encroachment in African savannas reflect water constraints and fire disturbance. Journal of biogeography, 45(6), 1209-1218.	2018	Africa	Botswana	Shrub/woodland cover gain	2002	2016
Axelsson, C. R., & Hanan, N. P. (2018). Rates of woody encroachment in African savannas reflect water constraints and fire disturbance. Journal of biogeography, 45(6), 1209-1218.	2018	Africa	Botswana	Shrub/woodland cover gain	2002	2016
Axelsson, C. R., & Hanan, N. P. (2018). Rates of woody encroachment in African savannas reflect water constraints and fire disturbance. Journal of biogeography, 45(6), 1209-1218.	2018	Africa	Chad	Shrub/woodland cover gain	2002	2016
Axelsson, C. R., & Hanan, N. P. (2018). Rates of woody encroachment in African savannas reflect water constraints and fire disturbance. Journal of biogeography, 45(6), 1209-1218.	2018	Africa	Chad	Shrub/woodland cover gain	2002	2016
Axelsson, C. R., & Hanan, N. P. (2018). Rates of woody encroachment in African savannas reflect water constraints and fire disturbance. Journal of biogeography, 45(6), 1209-1218.	2018	Africa	Ethiopa	Shrub/woodland cover gain	2002	2016
Axelsson, C. R., & Hanan, N. P. (2018). Rates of woody encroachment in African savannas reflect water constraints and fire disturbance. Journal of biogeography, 45(6), 1209-1218.	2018	Africa	Ethiopa	Shrub/woodland cover gain	2002	2016
Axelsson, C. R., & Hanan, N. P. (2018). Rates of woody encroachment in African savannas reflect water constraints and fire disturbance. Journal of biogeography, 45(6), 1209-1218.	2018	Africa	Ghana	Shrub/woodland cover gain	2002	2016
Axelsson, C. R., & Hanan, N. P. (2018). Rates of woody encroachment in African savannas reflect water constraints and fire disturbance. Journal of biogeography, 45(6), 1209-1218.	2018	Africa	Kenya	Shrub/woodland cover gain	2002	2016

Axelsson, C. R., & Hanan, N. P. (2018). Rates of woody encroachment in African savannas reflect water constraints and fire disturbance. Journal of biogeography, 45(6), 1209-1218.	2018	Africa	Mozambique	Shrub/woodland cover gain	2002	2016
Axelsson, C. R., & Hanan, N. P. (2018). Rates of woody encroachment in African savannas reflect water constraints and fire disturbance. Journal of biogeography, 45(6), 1209-1218.	2018	Africa	Mozambique	Shrub/woodland cover gain	2002	2016
Axelsson, C. R., & Hanan, N. P. (2018). Rates of woody encroachment in African savannas reflect water constraints and fire disturbance. Journal of biogeography, 45(6), 1209-1218.	2018	Africa	Namibia	Shrub/woodland cover gain	2002	2016
Axelsson, C. R., & Hanan, N. P. (2018). Rates of woody encroachment in African savannas reflect water constraints and fire disturbance. Journal of biogeography, 45(6), 1209-1218.	2018	Africa	Namibia	Shrub/woodland cover gain	2002	2016
Axelsson, C. R., & Hanan, N. P. (2018). Rates of woody encroachment in African savannas reflect water constraints and fire disturbance. Journal of biogeography, 45(6), 1209-1218.	2018	Africa	Namibia	Shrub/woodland cover gain	2002	2016
Axelsson, C. R., & Hanan, N. P. (2018). Rates of woody encroachment in African savannas reflect water constraints and fire disturbance. Journal of biogeography, 45(6), 1209-1218.	2018	Africa	Nigeria	Shrub/woodland cover gain	2002	2016
Axelsson, C. R., & Hanan, N. P. (2018). Rates of woody encroachment in African savannas reflect water constraints and fire disturbance. Journal of biogeography, 45(6), 1209-1218.	2018	Africa	Nigeria	Shrub/woodland cover gain	2002	2016
Axelsson, C. R., & Hanan, N. P. (2018). Rates of woody encroachment in African savannas reflect water constraints and fire disturbance. Journal of biogeography, 45(6), 1209-1218.	2018	Africa	Senegal	Shrub/woodland cover gain	2002	2016
Axelsson, C. R., & Hanan, N. P. (2018). Rates of woody encroachment in African savannas reflect water constraints and fire disturbance. Journal of biogeography, 45(6), 1209-1218.	2018	Africa	Somalia	Shrub/woodland cover gain	2002	2016
Axelsson, C. R., & Hanan, N. P. (2018). Rates of woody encroachment in African savannas reflect water constraints and fire disturbance. Journal of biogeography, 45(6), 1209-1218.	2018	Africa	Somalia	Shrub/woodland cover gain	2002	2016
Axelsson, C. R., & Hanan, N. P. (2018). Rates of woody encroachment in African savannas reflect water constraints and fire disturbance. Journal of biogeography, 45(6), 1209-1218.	2018	Africa	Somalia	Shrub/woodland cover gain	2002	2016
Axelsson, C. R., & Hanan, N. P. (2018). Rates of woody encroachment in African savannas reflect water constraints and fire disturbance. Journal of biogeography, 45(6), 1209-1218.	2018	Africa	South Africa	Shrub/woodland cover gain	2002	2016
Axelsson, C. R., & Hanan, N. P. (2018). Rates of woody encroachment in African savannas reflect water constraints and fire disturbance. Journal of biogeography, 45(6), 1209-1218.	2018	Africa	South Africa	Shrub/woodland cover gain	2002	2016

Axelsson, C. R., & Hanan, N. P. (2018). Rates of woody encroachment in African savannas reflect water constraints and fire disturbance. Journal of biogeography, 45(6), 1209-1218.	2018	Africa	Sudan	Shrub/woodland cover gain	2002	2016
Axelsson, C. R., & Hanan, N. P. (2018). Rates of woody encroachment in African savannas reflect water constraints and fire disturbance. Journal of biogeography, 45(6), 1209-1218.	2018	Africa	Sudan	Shrub/woodland cover gain	2002	2016
Axelsson, C. R., & Hanan, N. P. (2018). Rates of woody encroachment in African savannas reflect water constraints and fire disturbance. Journal of biogeography, 45(6), 1209-1218.	2018	Africa	Sudan	Shrub/woodland cover gain	2002	2016
Axelsson, C. R., & Hanan, N. P. (2018). Rates of woody encroachment in African savannas reflect water constraints and fire disturbance. Journal of biogeography, 45(6), 1209-1218.	2018	Africa	Tanzania	Shrub/woodland cover gain	2002	2016
Axelsson, C. R., & Hanan, N. P. (2018). Rates of woody encroachment in African savannas reflect water constraints and fire disturbance. Journal of biogeography, 45(6), 1209-1218.	2018	Africa	Tanzania	Shrub/woodland cover gain	2002	2016
Axelsson, C. R., & Hanan, N. P. (2018). Rates of woody encroachment in African savannas reflect water constraints and fire disturbance. Journal of biogeography, 45(6), 1209-1218.	2018	Africa	Tanzania	Shrub/woodland cover gain	2002	2016
Axelsson, C. R., & Hanan, N. P. (2018). Rates of woody encroachment in African savannas reflect water constraints and fire disturbance. Journal of biogeography, 45(6), 1209-1218.	2018	Africa	Uganda	Shrub/woodland cover gain	2002	2016
Axelsson, C. R., & Hanan, N. P. (2018). Rates of woody encroachment in African savannas reflect water constraints and fire disturbance. Journal of biogeography, 45(6), 1209-1218.	2018	Africa	Zambia	Shrub/woodland cover gain	2002	2016
Axelsson, C. R., & Hanan, N. P. (2018). Rates of woody encroachment in African savannas reflect water constraints and fire disturbance. Journal of biogeography, 45(6), 1209-1218.	2018	Africa	Zimbabwe	Shrub/woodland cover gain	2002	2016
Bassett, T. J., & Zuéli, K. B. (2000). Environmental discourses and the Ivorian Savanna. Annals of the Association of American Geographers, 90(1), 67-95.	2000	Africa	Ivory coast	Shrub/woodland cover gain	1956	1989
Bassett, T. J., & Zuéli, K. B. (2000). Environmental discourses and the Ivorian Savanna. Annals of the Association of American Geographers, 90(1), 67-95.	2000	Africa	Ivory coast	Shrub/woodland cover gain	1956	1993
Britz, M. L., & Ward, D. (2007). Dynamics of woody vegetation in a semi-arid savanna, with a focus on bush encroachment. African Journal of Range and Forage Science, 24(3), 131-140.	2007	Africa	South Africa	Shrub/woodland cover gain	1957	1993
Eckhardt, H. C., Wilgen, B. W., & Biggs, H. C. (2000). Trends in woody vegetation cover in the Kruger National Park, South Africa, between 1940 and 1998. African Journal of Ecology, 38(2), 108-115.	2000	Africa	South Africa	Shrub/woodland cover gain	1940	1998

Gautier, L. (1989). Contact forêt-savane en Côte d'Ivoire centrale: évolution de la surface forestière de la réserve de Lamto (sud du V-Baoulé). Bulletin de la Société Botanique de France, 136(3), 85-92.	1989	Africa	Ivory coast	Forest cover gain	1963	1988
Gautier, L. (1989). Contact forêt-savane en Côte d'Ivoire centrale: évolution de la surface forestière de la réserve de Lamto (sud du V-Baoulé). Bulletin de la Société Botanique de France, 136(3), 85-92.	1989	Africa	Ivory coast	Shrub/woodland cover gain	1963	1988
Goetze, D., Hörsch, B., & Porembski, S. (2006). Dynamics of forest–savanna mosaics in north-eastern Ivory Coast from 1954 to 2002. Journal of Biogeography, 33(4), 653-664.	2006	Africa	Guinea	Forest cover gain	1954	1996
Gordijn, P. J., Rice, E., & Ward, D. (2012). The effects of fire on woody plant encroachment are exacerbated by succession of trees of decreased palatability. Perspectives in Plant Ecology, Evolution and Systematics, 14(6), 411-422.	2012	Africa	South Africa	Shrub/woodland cover gain	1943	2007
Grellier, S., Kemp, J., Janeau, J. L., Florsch, N., Ward, D., Barot, S., ... & Valentin, C. (2012). The indirect impact of encroaching trees on gully extension: A 64year study in a sub-humid grassland of South Africa. Catena, 98, 110-119.	2012	Africa	South Africa	Shrub/woodland cover gain	1945	2009
Guillet, B., Achoundong, G., Happi, J. Y., Beyala, V. K. K., Bonvallot, J., Riera, B., ... & Schwartz, D. (2001). Agreement between floristic and soil organic carbon isotope (13C/12C, 14C) indicators of forest invasion of savannas during the last century in Cameroon. Journal of Tropical Ecology, 17(06), 809-832.	2001	Africa	Cameroon	Forest cover gain	1952	1993
Hottman, M. T., & O'Connor, T. G. (1999). Vegetation change over 40 years in the Weenen/Muden area, KwaZulu-Natal: evidence from photo-panoramas.African Journal of Range and Forage Science, 16(2-3), 71-88.	1999	Africa	South Africa	Shrub/woodland cover gain	1955	1998
Hudak, A. T., & Wessman, C. A. (2001). Textural analysis of high resolution imagery to quantify bush encroachment in Madikwe Game Reserve, South Africa, 1955-1996. International Journal of Remote Sensing, 22(14), 2731-2740.	2001	Africa	South Africa	Shrub/woodland cover gain	1955	1996
Kakembo, V. (2001). Trends in vegetation degradation in relation to land tenure, rainfall, and population changes in Peddie district, Eastern Cape, South Africa.Environmental Management, 28(1), 39-46.	2001	Africa	South Africa	Shrub/woodland cover gain	1938	1988
Levick, S. R., & Rogers, K. H. (2011). Context-dependent vegetation dynamics in an African savanna. Landscape ecology, 26(4), 515-528.	2011	Africa	South Africa	Shrub/woodland cover gain	1942	2001
Levick, S. R., & Rogers, K. H. (2011). Context-dependent vegetation dynamics in an African savanna. Landscape ecology, 26(4), 515-528.	2011	Africa	South Africa	Shrub/woodland cover gain	1942	2001

Mapedza, E., Wright, J., & Fawcett, R. (2003). An investigation of land cover change in Mafungautsi Forest, Zimbabwe, using GIS and participatory mapping.Applied Geography, 23(1), 1-21.	2003	Africa	Zimbabwe	Forest cover gain	1976	1996
Marston, C. G., Aplin, P., Wilkinson, D. M., Field, R., & O'Regan, H. J. (2017). Scrubbing up: multi-scale investigation of woody encroachment in a southern African savannah. Remote Sensing, 9(5), 419.	2017	Africa	South Africa	Shrub/woodland cover gain	2001	2014
Mitchard, E. T. A., Saatchi, S. S., Gerard, F. F., Lewis, S. L., & Meir, P. (2009). Measuring woody encroachment along a forest-savanna boundary in Central Africa. Earth Interactions, 13(8), 1-29.	2009	Africa	Cameroon	Forest cover gain	1986	2006
Mosugelo, D. K., Moe, S. R., Ringrose, S., & Nellemann, C. (2002). Vegetation changes during a 36-year period in northern Chobe National Park, Botswana.African Journal of Ecology, 40(3), 232-240.	2002	Africa	Botswana	Shrub/woodland cover gain	1962	1998
O'Connor, T. G. (2001). Effect of small catchment dams on downstream vegetation of a seasonal river in semi-arid African savanna. Journal of Applied Ecology, 38(6), 1314-1325.	2001	Africa	South Africa	Shrub/woodland cover gain	1955	1987
O'Connor, T. G., & Crow, V. R. T. (1999). Rate and pattern of bush encroachment in Eastern Cape savanna and grassland. African Journal of Range and Forage Science, 16(1), 26-31.	1999	Africa	South Africa	Shrub/woodland cover gain	1938	1986
O'connor, T. G., Haines, L. M., & Snyman, H. A. (2001). Influence of precipitation and species composition on phytomass of a semi-arid African grassland. Journal of Ecology, 89(5), 850-860.	2001	Africa	South Africa	Shrub/woodland cover gain	1955	1987
Poulsen, Z.C. and Hoffman, M.T., 2015. Changes in the distribution of indigenous forest in Table Mountain National Park during the 20th Century. South African Journal of Botany. 101, 49-56.	2015	Africa	South Africa	Forest cover gain	1944	2008
Prins, H. H., & van der Jeugd, H. P. (1993). Herbivore population crashes and woodland structure in East Africa. Journal of Ecology, 305-314.	1993	Africa	Tanzania	Shrub/woodland cover gain	1985	1991
Prins, H. H., & van der Jeugd, H. P. (1993). Herbivore population crashes and woodland structure in East Africa. Journal of Ecology, 305-314.	1993	Africa	Tanzania	Shrub/woodland cover gain	1985	1991
Prins, H. H., & van der Jeugd, H. P. (1993). Herbivore population crashes and woodland structure in East Africa. Journal of Ecology, 305-314.	1993	Africa	Tanzania	Shrub/woodland cover gain	1985	1991
Prins, H. H., & van der Jeugd, H. P. (1993). Herbivore population crashes and woodland structure in East Africa. Journal of Ecology, 305-314.	1993	Africa	Tanzania	Shrub/woodland cover gain	1985	1991
Puttick, J. R., Hoffman, M. T., & Gambiza, J. (2011). Historical and recent land-use impacts on the vegetation of Bathurst, a municipal commonage in the Eastern Cape, South Africa. African Journal of Range & Forage Science, 28(1), 9-20.	2011	Africa	South Africa	Shrub/woodland cover gain	1942	2004

Puttick, J. R., Hoffman, M. T., & Gambiza, J. (2011). Historical and recent land-use impacts on the vegetation of Bathurst, a municipal commonage in the Eastern Cape, South Africa. African Journal of Range & Forage Science, 28(1), 9-20.	2011	Africa	South Africa	Shrub/woodland cover gain	1942	2004
Puttick, J. R., Hoffman, M. T., & Gambiza, J. (2011). Historical and recent land-use impacts on the vegetation of Bathurst, a municipal commonage in the Eastern Cape, South Africa. African Journal of Range & Forage Science, 28(1), 9-20.	2011	Africa	South Africa	Shrub/woodland cover gain	1942	2004
Puttick, J. R., Hoffman, M. T., & Gambiza, J. (2014). The impact of land use on woody plant cover and species composition on the Grahamstown municipal commonage: implications for South Africa's land reform programme. African Journal of Range & Forage Science, 31(2), 123-133.	2014	Africa	South Africa	Shrub/woodland cover gain	1942	2004
Puttick, J. R., Hoffman, M. T., & Gambiza, J. (2014). The influence of South Africa's post-apartheid land reform policies on bush encroachment and range condition: a case study of Fort Beaufort's municipal commonage. African Journal of Range & Forage Science, (ahead-of-print), 1-11.	2014	Africa	South Africa	Shrub/woodland cover gain	1949	2004
Puttick, J. R., Hoffman, M. T., & Gambiza, J. (2014). The influence of South Africa's post-apartheid land reform policies on bush encroachment and range condition: a case study of Fort Beaufort's municipal commonage. African Journal of Range & Forage Science, (ahead-of-print), 1-11.	2014	Africa	South Africa	Shrub/woodland cover gain	1949	2004
Puttick, J. R., Hoffman, M. T., & Gambiza, J. (2014). The influence of South Africa's post-apartheid land reform policies on bush encroachment and range condition: a case study of Fort Beaufort's municipal commonage. African Journal of Range & Forage Science, (ahead-of-print), 1-11.	2014	Africa	South Africa	Shrub/woodland cover gain	1949	2004
Rohde, R. F., & Hoffman, M. T. (2012). The historical ecology of Namibian rangelands: Vegetation change since 1876 in response to local and global drivers. Science of the Total Environment, 416, 276-288.	2012	Africa	namibia	Shrub/woodland cover gain	1876	2009
Rohde, R. F., & Hoffman, M. T. (2012). The historical ecology of Namibian rangelands: Vegetation change since 1876 in response to local and global drivers. Science of the Total Environment, 416, 276-288.	2012	Africa	namibia	Shrub/woodland cover gain	1876	2009
Rohde, R. F., Hoffman, M. T., Durbach, I., Venter, Z., & Jack, S. (2019). Vegetation and climate change in the Pro-Namib and Namib Desert based on repeat photography: Insights into climate trends. Journal of Arid Environments, 165, 119-131.	2019	Africa	Namibia	Shrub/woodland cover gain	1876	2016
Rohde, R. F., Hoffman, M. T., Durbach, I., Venter, Z., & Jack, S. (2019). Vegetation and climate change in the Pro-Namib and Namib Desert based on repeat photography: Insights	2019	Africa	Namibia	Shrub/woodland cover gain	1876	2016

into climate trends. Journal of Arid Environments, 165, 119-131.						
Roques, K. G., O'connor, T. G., & Watkinson, A. R. (2001). Dynamics of shrub encroachment in an African savanna: relative influences of fire, herbivory, rainfall and density dependence. Journal of Applied Ecology, 38(2), 268-280.	2001	Africa	Swaziland	Shrub/woodland cover gain	1947	1997
Roques, K. G., O'connor, T. G., & Watkinson, A. R. (2001). Dynamics of shrub encroachment in an African savanna: relative influences of fire, herbivory, rainfall and density dependence. Journal of Applied Ecology, 38(2), 268-280.	2001	Africa	Swaziland	Shrub/woodland cover gain	1947	1997
Roques, K. G., O'connor, T. G., & Watkinson, A. R. (2001). Dynamics of shrub encroachment in an African savanna: relative influences of fire, herbivory, rainfall and density dependence. Journal of Applied Ecology, 38(2), 268-280.	2001	Africa	Swaziland	Shrub/woodland cover gain	1947	1997
Roques, K. G., O'connor, T. G., & Watkinson, A. R. (2001). Dynamics of shrub encroachment in an African savanna: relative influences of fire, herbivory, rainfall and density dependence. Journal of Applied Ecology, 38(2), 268-280.	2001	Africa	Swaziland	Shrub/woodland cover gain	1947	1997
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Roques, K. G., O'connor, T. G., & Watkinson, A. R. (2001). Dynamics of shrub encroachment in an African savanna: relative influences of fire, herbivory, rainfall and density dependence. Journal of Applied Ecology, 38(2), 268-280.	2001	Africa	Swaziland	Shrub/woodland cover gain	1947	1997
Russell, J. M., & Ward, D. (2014). Remote sensing provides a progressive record of vegetation change in northern KwaZulu-Natal, South Africa, from 1944 to 2005. International Journal of Remote Sensing, 35(3), 904-926.	2014	Africa	South Africa	Shrub/woodland cover gain	1944	2005
Russell, J. M., & Ward, D. (2014). Remote sensing provides a progressive record of vegetation change in northern KwaZulu-Natal, South Africa, from 1944 to 2005. International Journal of Remote Sensing, 35(3), 904-926.	2014	Africa	South Africa	Shrub/woodland cover gain	1944	2005
Russell, J. M., & Ward, D. (2014). Remote sensing provides a progressive record of vegetation change in northern KwaZulu-Natal, South Africa, from 1944 to 2005. International Journal of Remote Sensing, 35(3), 904-926.	2014	Africa	South Africa	Shrub/woodland cover gain	1944	2005

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Russell, J., & Ward, D. (2013). Vegetation change in northern KwaZulu-Natal since the Anglo-Zulu War of 1879: local or global drivers?. African Journal of Range & Forage Science, (ahead-of-print), 1-17.	2013	Africa	South Africa	Shrub/woodland cover gain	1879	2011
Stevens et al unpublished	2016	Africa	South Africa	Shrub/woodland cover gain	1940	2009
Ward, D., Hoffman, M. T., & Collocott, S. J. (2014). A century of woody plant encroachment in the dry Kimberley savanna of South Africa. African Journal of Range & Forage Science, (ahead-of-print), 1-15.	2014	Africa	South Africa	Shrub/woodland cover gain	1940	2009
Ward, D., Hoffman, M. T., & Collocott, S. J. (2014). A century of woody plant encroachment in the dry Kimberley savanna of South Africa. African Journal of Range & Forage Science, (ahead-of-print), 1-15.	2014	Africa	South Africa	Shrub/woodland cover gain	1900	2010
Ward, D., Hoffman, M. T., & Collocott, S. J. (2014). A century of woody plant encroachment in the dry Kimberley savanna of South Africa. African Journal of Range & Forage Science, (ahead-of-print), 1-15.	2014	Africa	South Africa	Shrub/woodland cover gain	1899	2010
Ward, D., Hoffman, M. T., & Collocott, S. J. (2014). A century of woody plant encroachment in the dry Kimberley savanna of South Africa. African Journal of Range & Forage Science, (ahead-of-print), 1-15.	2014	Africa	South Africa	Shrub/woodland cover gain	1989	2010
Wigley, B. J., Bond, W. J., & Hoffman, M. (2010). Thicket expansion in a South African savanna under divergent land use: local vs. global drivers?. Global Change Biology, 16(3), 964-976.	2010	Africa	South Africa	Shrub/woodland cover gain	1937	2004
Wigley, B. J., Bond, W. J., & Hoffman, M. (2010). Thicket expansion in a South African savanna under divergent land use: local vs. global drivers?. Global Change Biology, 16(3), 964-976.	2010	Africa	South Africa	Shrub/woodland cover gain	1937	2004
Wigley, B. J., Bond, W. J., & Hoffman, M. (2010). Thicket expansion in a South African savanna under divergent land use: local vs. global drivers?. Global Change Biology, 16(3), 964-976.	2010	Africa	South Africa	Shrub/woodland cover gain	1937	2004
Masubelele, M. L., Hoffman, M. T., & Bond, W. J. (2015). A repeat photograph analysis of long-term vegetation change in semi-arid South Africa in response to land use and climate. Journal of Vegetation Science, 26(5), 1013-1023.	2015	Africa	South Africa	Herbaceous cover gain	1950	2010
Masubelele, M. L., Hoffman, M. T., & Bond, W. J. (2015). A repeat photograph analysis of long-term vegetation change in semi-arid South Africa in response to land use and climate. Journal of Vegetation Science, 26(5), 1013-1023.	2015	Africa	South Africa	Herbaceous cover gain	1950	2010

Masubelele, M. L., Hoffman, M. T., & Bond, W. J. (2015). A repeat photograph analysis of long-term vegetation change in semi-arid South Africa in response to land use and climate. Journal of Vegetation Science, 26(5), 1013-1023.	2015	Africa	South Africa	Shrub/woodland cover gain	1950	2010
Masubelele, M. L., Hoffman, M. T., & Bond, W. J. (2015). A repeat photograph analysis of long-term vegetation change in semi-arid South Africa in response to land use and climate. Journal of Vegetation Science, 26(5), 1013-1023.	2015	Africa	South Africa	Shrub/woodland cover gain	1950	2010
Brandt, M., Hiernaux, P., Rasmussen, K., Tucker, C. J., Wigneron, J. P., Diouf, A. A., ... & Abel, C. (2019). Changes in rainfall distribution promote woody foliage production in the Sahel. Communications biology, 2(1), 1-10.	2019	Africa	Sahel	Herbaceous cover gain	1987	2016
Brandt, M., Hiernaux, P., Rasmussen, K., Tucker, C. J., Wigneron, J. P., Diouf, A. A., ... & Abel, C. (2019). Changes in rainfall distribution promote woody foliage production in the Sahel. Communications biology, 2(1), 1-10.	2019	Africa	Sahel	Herbaceous cover gain	1987	2016
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Brandt, M., Hiernaux, P., Rasmussen, K., Tucker, C. J., Wigneron, J. P., Diouf, A. A., ... & Abel, C. (2019). Changes in rainfall distribution promote woody foliage production in the Sahel. Communications biology, 2(1), 1-10.	2019	Africa	Sahel	Shrub/woodland cover gain	1987	2016
Brandt, M., Hiernaux, P., Rasmussen, K., Tucker, C. J., Wigneron, J. P., Diouf, A. A., ... & Abel, C. (2019). Changes in rainfall distribution promote woody foliage production in the Sahel. Communications biology, 2(1), 1-10.	2019	Africa	Sahel	Shrub/woodland cover gain	1987	2016
Brandt, M., Hiernaux, P., Rasmussen, K., Tucker, C. J., Wigneron, J. P., Diouf, A. A., ... & Abel, C. (2019). Changes in rainfall distribution promote woody foliage production in the Sahel. Communications biology, 2(1), 1-10.	2019	Africa	Sahel	Shrub/woodland cover gain	1987	2016
Brandt, M., Hiernaux, P., Rasmussen, K., Tucker, C. J., Wigneron, J. P., Diouf, A. A., ... & Abel, C. (2019). Changes in rainfall distribution promote woody foliage production in the Sahel. Communications biology, 2(1), 1-10.	2019	Africa	Sahel	Shrub/woodland cover gain	1987	2016
Brandt, M., Hiernaux, P., Rasmussen, K., Tucker, C. J., Wigneron, J. P., Diouf, A. A., ... & Abel, C. (2019). Changes in rainfall distribution promote woody foliage production in the Sahel. Communications biology, 2(1), 1-10.	2019	Africa	Sahel	Herbaceous cover gain	1987	2016
Brandt, M., Hiernaux, P., Rasmussen, K., Tucker, C. J., Wigneron, J. P., Diouf, A. A., ... & Abel, C. (2019). Changes in rainfall distribution promote woody foliage production in the Sahel. Communications biology, 2(1), 1-10.	2019	Africa	Sahel	Herbaceous cover gain	1987	2016
Brandt, M., Hiernaux, P., Rasmussen, K., Tucker, C. J., Wigneron, J. P., Diouf, A. A., ... & Abel, C. (2019). Changes in rainfall distribution promote woody foliage production in the Sahel. Communications biology, 2(1), 1-10.	2019	Africa	Sahel	Herbaceous cover gain	1987	2016
Brandt, M., Hiernaux, P., Rasmussen, K., Tucker, C. J., Wigneron, J. P., Diouf, A. A., ... & Abel, C. (2019). Changes in rainfall distribution promote woody foliage production in the Sahel. Communications biology, 2(1), 1-10.	2019	Africa	Sahel	Herbaceous cover gain	1987	2016
Brandt, M., Hiernaux, P., Rasmussen, K., Tucker, C. J., Wigneron, J. P., Diouf, A. A., ... & Abel, C. (2019). Changes in rainfall distribution promote woody foliage production in the Sahel. Communications biology, 2(1), 1-10.	2019	Africa	Sahel	Herbaceous cover gain	1987	2016
Li, W., Buitenwerf, R., Munk, M., Bøcher, P. K., & Svenning, J. C. (2020). Deep-learning based high-resolution mapping shows woody vegetation densification in greater Maasai Mara ecosystem. Remote Sensing of Environment, 247, 111953.	2020	Africa	Kenya	Shrub/woodland cover gain	2015	2018

Li, W., Buitenwerf, R., Munk, M., Bøcher, P. K., & Svenning, J. C. (2020). Deep-learning based high-resolution mapping shows woody vegetation densification in greater Maasai Mara ecosystem. Remote Sensing of Environment, 247, 111953.	2020	Africa	Kenya	Shrub/woodland cover gain	2015	2018
Li, W., Buitenwerf, R., Munk, M., Bøcher, P. K., & Svenning, J. C. (2020). Deep-learning based high-resolution mapping shows woody vegetation densification in greater Maasai Mara ecosystem. Remote Sensing of Environment, 247, 111953.	2020	Africa	Kenya	Shrub/woodland cover gain	2015	2018
Venter, Z. S., Scott, S. L., Desmet, P. G., & Hoffman, M. T. (2020). Application of Landsat-derived vegetation trends over South Africa: Potential for monitoring land degradation and restoration. Ecological Indicators, 113, 106206.	2020	Africa	South Africa	Shrub/woodland cover gain	1948	2018
Venter, Z. S., Scott, S. L., Desmet, P. G., & Hoffman, M. T. (2020). Application of Landsat-derived vegetation trends over South Africa: Potential for monitoring land degradation and restoration. Ecological Indicators, 113, 106206.	2020	Africa	South Africa	Herbaceous cover gain	1968	2018
Venter, Z. S., Scott, S. L., Desmet, P. G., & Hoffman, M. T. (2020). Application of Landsat-derived vegetation trends over South Africa: Potential for monitoring land degradation and restoration. Ecological Indicators, 113, 106206.	2020	Africa	South Africa	Herbaceous cover gain	2004	2018
Venter, Z. S., Scott, S. L., Desmet, P. G., & Hoffman, M. T. (2020). Application of Landsat-derived vegetation trends over South Africa: Potential for monitoring land degradation and restoration. Ecological Indicators, 113, 106206.	2020	Africa	South Africa	Grass cover loss	1987	2013
Aleman, J. C., Jarzyna, M. A., & Staver, A. C. (2018). Forest extent and deforestation in tropical Africa since 1900. Nature ecology & evolution, 2(1), 26-33.	2018	Africa	Central African republic	Forest cover gain		
Aleman, J. C., Jarzyna, M. A., & Staver, A. C. (2018). Forest extent and deforestation in tropical Africa since 1900. Nature ecology & evolution, 2(1), 26-33.	2018	Africa	Gabon	Forest cover gain		
Skowno, A. L., Thompson, M. W., Hiestermann, J., Ripley, B., West, A. G., & Bond, W. J. (2017). Woodland expansion in South African grassy biomes based on satellite observations (1990–2013): general patterns and potential drivers. Global Change Biology, 23(6), 2358–2369. https://doi.org/10.1111/gcb.13529	2017	Africa	South Africa	Shrub/woodland cover gain	1990	2013
Banfai, Daniel S., and David MJS Bowman. "Forty years of lowland monsoon rainforest expansion in Kakadu National Park, Northern Australia." Biological Conservation 131.4 (2006): 553-565.	2006	Australasia	Australia	Forest cover gain	1964	2004
Banfai, Daniel S., and David MJS Bowman. "Forty years of lowland monsoon rainforest expansion in Kakadu National Park, Northern Australia." Biological Conservation 131.4 (2006): 553-565.	2006	Australasia	Australia	Forest cover gain	1964	2004

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Banfai, Daniel S., and David MJS Bowman. "Forty years of lowland monsoon rainforest expansion in Kakadu National Park, Northern Australia." Biological Conservation 131.4 (2006): 553-565.	2006	Australasia	Australia	Forest cover gain	1964	2004
Banfai, Daniel S., and David MJS Bowman. "Forty years of lowland monsoon rainforest expansion in Kakadu National Park, Northern Australia." Biological Conservation 131.4 (2006): 553-565.	2006	Australasia	Australia	Forest cover gain	1964	2004
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Banfai, Daniel S., and David MJS Bowman. "Forty years of lowland monsoon rainforest expansion in Kakadu National Park, Northern Australia." Biological Conservation 131.4 (2006): 553-565.	2006	Australasia	Australia	Forest cover gain	1964	2004
Banfai, Daniel S., and David MJS Bowman. "Forty years of lowland monsoon rainforest expansion in Kakadu National Park, Northern Australia." Biological Conservation 131.4 (2006): 553-565.	2006	Australasia	Australia	Forest cover gain	1964	2004
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Banfai, Daniel S., and David MJS Bowman. "Forty years of lowland monsoon rainforest expansion in Kakadu National Park, Northern Australia." Biological Conservation 131.4 (2006): 553-565.	2006	Australasia	Australia	Forest cover gain	1964	2004
Banfai, Daniel S., and David MJS Bowman. "Forty years of lowland monsoon rainforest expansion in Kakadu National Park, Northern Australia." Biological Conservation 131.4 (2006): 553-565.	2006	Australasia	Australia	Forest cover gain	1964	2004
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Banfai, Daniel S., and David MJS Bowman. "Forty years of lowland monsoon rainforest expansion in Kakadu National Park, Northern Australia." Biological Conservation 131.4 (2006): 553-565.	2006	Australasia	Australia	Forest cover gain	1964	2004

Banfai, Daniel S., and David MJS Bowman. "Forty years of lowland monsoon rainforest expansion in Kakadu National Park, Northern Australia." Biological Conservation 131.4 (2006): 553-565.	2006	Australasia	Australia	Forest cover gain	1964	2004
Banfai, Daniel S., and David MJS Bowman. "Forty years of lowland monsoon rainforest expansion in Kakadu National Park, Northern Australia." Biological Conservation 131.4 (2006): 553-565.	2006	Australasia	Australia	Forest cover gain	1964	2004
Bowman and Dingle 2006	2006	Australasia	Australia	Forest cover gain	1964	2004
Bowman and Dingle 2006	2006	Australasia	Australia	Forest cover gain	1964	2004
Bowman and Dingle 2006	2006	Australasia	Australia	Forest cover gain	1964	2004
Bowman and Dingle 2006	2006	Australasia	Australia	Forest cover gain	1964	2004
Bowman and Dingle 2006	2006	Australasia	Australia	Forest cover gain	1964	2004
Bowman and Dingle 2006	2006	Australasia	Australia	Forest cover gain	1964	2004
Bowman and Dingle 2006	2006	Australasia	Australia	Forest cover gain	1964	2004
Bowman and Dingle 2006	2006	Australasia	Australia	Forest cover gain	1964	2004
Bowman and Dingle 2006	2006	Australasia	Australia	Forest cover gain	1964	2004
Bowman and Dingle 2006	2006	Australasia	Australia	Forest cover gain	1964	2004
Bowman and Dingle 2006	2006	Australasia	Australia	Forest cover gain	1964	2004
Bowman and Dingle 2006	2006	Australasia	Australia	Forest cover gain	1964	2004
Bowman et al 2001	2001	Australasia	Australia	Forest cover gain	1941	1994
Bowman, D. M. J. S., Walsh, A., & Milne, D. J. (2001). Forest expansion and grassland contraction within a Eucalyptus savanna matrix between 1941 and 1994 at Litchfield National Park in the Australian monsoon tropics. Global Ecology and Biogeography, 10(5), 535-548.	2001	Australasia	Australia	Forest cover gain	1941	1999
Brook and Bowman 2006	2006	Australasia	Australia	Forest cover gain	1947	1997
Brook and Bowman 2006	2006	Australasia	Australia	Forest cover gain	1947	1997
Brook and Bowman 2006	2006	Australasia	Australia	Forest cover gain	1947	1997
Brook and Bowman 2006	2006	Australasia	Australia	Forest cover gain	1947	1997
Brook and Bowman 2006	2006	Australasia	Australia	Forest cover gain	1947	1997
Burrows, W.H, Henry, B.K., Back, P.V., Hoffman, M.B., Tait, L.J., Anderson, E.R., Menke, N., Danaher, T., Carter, J.O., and McKeon, G.M. (2002). Growth and carbon stock change in eucalypt woodlands in northeast Australia: ecological and greenhouse sink implications. Global Change Biology, 8(8), 769-784.	2002	Australasia	Australia	Shrub/woodl and cover gain	1984	1999

Fensham, R. J., Choy, S. J. L., Fairfax, R. J., & Cavallaro, P. C. 2003. Modelling trends in woody vegetation structure in semi-arid Australia as determined from aerial photography. Journal of Environmental Management, 68(4), 421-436.	2003	Australasia	Australia	Shrub/woodl and cover gain	1960	1996
Fensham, R. J., Choy, S. J. L., Fairfax, R. J., & Cavallaro, P. C. 2003. Modelling trends in woody vegetation structure in semi-arid Australia as determined from aerial photography. Journal of Environmental Management, 68(4), 421-436.	2003	Australasia	Australia	Shrub/woodl and cover gain	1951	1996
Fensham, R. J., Choy, S. J. L., Fairfax, R. J., & Cavallaro, P. C. 2003. Modelling trends in woody vegetation structure in semi-arid Australia as determined from aerial photography. Journal of Environmental Management, 68(4), 421-436.	2003	Australasia	Australia	Shrub/woodl and cover gain	1952	1994
Fensham, R. J., Choy, S. J. L., Fairfax, R. J., & Cavallaro, P. C. 2003. Modelling trends in woody vegetation structure in semi-arid Australia as determined from aerial photography. Journal of Environmental Management, 68(4), 421-436.	2003	Australasia	Australia	Shrub/woodl and cover gain	1952	1993
Lehmann et al 2009	2009	Australasia	Australia	Shrub/woodl and cover gain	1964	2004
McDougall K L 2003 Aerial photographic interpretation of vegetation changes on the Bogong High Plains Victoria between 1936 and 1980 Aust. J. Bot. 51 251–6	2003	Australasia	Australia	Shrub/woodl and cover gain	1936	1980
McDougall K L 2003 Aerial photographic interpretation of vegetation changes on the Bogong High Plains Victoria between 1936 and 1980 Aust. J. Bot. 51 251–6	2003	Australasia	Australia	Shrub/woodl and cover gain	1936	1980
McDougall K L 2003 Aerial photographic interpretation of vegetation changes on the Bogong High Plains Victoria between 1936 and 1980 Aust. J. Bot. 51 251–6	2003	Australasia	Australia	Herbaceous cover gain	1936	1980
McDougall K L 2003 Aerial photographic interpretation of vegetation changes on the Bogong High Plains Victoria between 1936 and 1980 Aust. J. Bot. 51 251–6	2003	Australasia	Australia	Forest cover gain	1936	1980
Ropars, P., É. Comeau, W. G. Lee, and S. Boudreau. 2018. Biome transition in a changing world: From indigenous grasslands to shrub-dominated communities. New Zealand Journal of Ecology 42:229–239.	2018	Australasia	New Zealand	Shrub/woodl and cover gain	1980	2015
Russell-Smith, Jeremy, et al. "Rain forest invasion of eucalypt-dominated woodland savanna, Iron Range, north-eastern Australia: II. Rates of landscape change." Journal of Biogeography 31.8 (2004): 1305-1316.	2004	Australasia	Australia	Forest cover gain	1943	1991
Scherrer P and Pickering C 2005 Recovery of alpine vegetation from grazing and drought: data from long-term photoquadrats in Kosciuszko National Park, Australia Arct. Antarct. Alp. Res. 37574–84	2005	Australasia	Australia	Shrub/woodl and cover gain	1959	2001

Sharp, B.R. and Bowmann, D.M.J.S. 2004. Patterns of long-term woody vegetation change in a sandstone-plateau savanna woodland, Northern Territory, Australia. Journal of Tropical Ecology, 20:259-270.	2004	Australasia	Australia	Shrub/woodland cover gain	1948	1995
Sharp, B.R. and Bowmann, D.M.J.S. 2004. Patterns of long-term woody vegetation change in a sandstone-plateau savanna woodland, Northern Territory, Australia. Journal of Tropical Ecology, 20:259-270.	2004	Australasia	Australia	Shrub/woodland cover gain	1948	1993
Sharp, B.R. and Bowmann, D.M.J.S. 2004. Patterns of long-term woody vegetation change in a sandstone-plateau savanna woodland, Northern Territory, Australia. Journal of Tropical Ecology, 20:259-270.	2004	Australasia	Australia	Shrub/woodland cover gain	1948	1993
Sharp, B.R. and Bowmann, D.M.J.S. 2004. Patterns of long-term woody vegetation change in a sandstone-plateau savanna woodland, Northern Territory, Australia. Journal of Tropical Ecology, 20:259-270.	2004	Australasia	Australia	Shrub/woodland cover gain	1948	1993
Sharp, B.R. and Bowmann, D.M.J.S. 2004. Patterns of long-term woody vegetation change in a sandstone-plateau savanna woodland, Northern Territory, Australia. Journal of Tropical Ecology, 20:259-270.	2004	Australasia	Australia	Shrub/woodland cover gain	1948	1993
Tng et al 2011	2011	Australasia	Australia	Forest cover gain	1951-55	2008
Tng et al 2011	2011	Australasia	Australia	Forest cover gain	1955	2008
Tng et al 2011	2011	Australasia	Australia	Forest cover gain	1949	2008
Tng et al 2011	2011	Australasia	Australia	Forest cover gain	1951	2008
Tng et al 2011	2011	Australasia	Australia	Forest cover gain	1950	2008
Williamson, G.J., Boggs, G.S. and Bowman, D.M., 2011. Late 20th century mangrove encroachment in the coastal Australian monsoon tropics parallels the regional increase in woody biomass. Regional Environmental Change. 11, 19-27.	2011	Australasia	Australia	Shrub/woodland cover gain	1974	2004
Witt et al 2006	2006	Australasia	Australia	Shrub/woodland cover gain	1930	1995
Witt, G.B., Harrington, R.A., and Page, M.J. 2009. Is‘vegetation thickening’ occurring in Queensland’s mulga lands – a 50-year aerial photographic analysis. Austral Journal of Botany, 57:572-582.	2009	Australasia	Australia	Shrub/woodland cover gain	1950	2000
Witt, G.B., Harrington, R.A., and Page, M.J. 2009. Is‘vegetation thickening’ occurring in Queensland’s mulga lands – a 50-year aerial photographic analysis. Austral Journal of Botany, 57:572-582.	2009	Australasia	Australia	Shrub/woodland cover gain	1950	2000
Witt, G.B., Harrington, R.A., and Page, M.J. 2009. Is‘vegetation thickening’ occurring in Queensland’s mulga lands – a 50-year aerial photographic analysis. Austral Journal of Botany, 57:572-582.	2009	Australasia	Australia	Shrub/woodland cover gain	1950	2000

Ondei, S., Prior, L. D., Vigilante, T., & Bowman, D. M. (2017). Fire and cattle disturbance affects vegetation structure and rain forest expansion into savanna in the Australian monsoon tropics. *Journal of biogeography*, *44*(10), 2331-2342.	2017	Australasia	Australia	Forest cover gain	1949	2005
Ondei, S., Prior, L. D., Vigilante, T., & Bowman, D. M. (2017). Fire and cattle disturbance affects vegetation structure and rain forest expansion into savanna in the Australian monsoon tropics. *Journal of biogeography*, *44*(10), 2331-2342.	2017	Australasia	Australia	Forest cover gain	1949	2005
Banfai, D. S., & Bowman, D. M. (2006). Forty years of lowland monsoon rainforest expansion in Kakadu National Park, northern Australia. *Biological Conservation*, *131*(4), 553-565.	2006	Australasia	Australia	Forest cover gain	1964	2004
Stanton, P., Stanton, D., Stott, M., & Parsons, M. (2014). Fire exclusion and the changing landscape of Queensland's Wet Tropics Bioregion 1. The extent and pattern of transition. *Australian Forestry*, *77*(1), 51-57.	2014	Australasia	Australia	Forest cover gain	1980	2013
Endress, B.A. and Chinea, J.D., 2001. Landscape Patterns of Tropical Forest Recovery in the Republic of Palau 1. Biotropica, 33(4), pp.555-565.	2001	Australasia	Palau	Forest cover gain	1947	1992
Florentine, S.K. and Westbrooke, M.E., 2004. Evaluation of alternative approaches to rainforest restoration on abandoned pasturelands in tropical north Queensland, Australia. Land Degradation & Development, 15(1), pp.1-13.	2004	Australasia	Australia	Forest cover gain	1970	2003
Anderson, K., Fawcett, D., Cugulliere, A., Benford, S., Jones, D., & Leng, R. (2020). Vegetation expansion in the subnival Hindu Kush Himalaya. Global Change Biology, 26(3), 1608–1625. https://doi.org/10.1111/gcb.14919	2020	Asia	Nepal	Shrub/woodland cover gain	1993	2018
Anderson, K., Fawcett, D., Cugulliere, A., Benford, S., Jones, D., & Leng, R. (2020). Vegetation expansion in the subnival Hindu Kush Himalaya. Global Change Biology, 26(3), 1608–1625. https://doi.org/10.1111/gcb.14919	2020	Asia	Nepal	Shrub/woodland cover gain	1993	2018
B. B. Baker & R. K. Moseley (2007) Advancing Treeline and Retreating Glaciers: Implications for Conservation in Yunnan, P.R. China, Arctic, Antarctic, and Alpine Research, 39:2, 200-209, DOI: 10.1657/1523-0430(2007)39[200:ATARGI]2.0.CO;2	2007	Asia	China	Forest cover gain		
Blok D, Sass-Klaassen U, Schaepman-Strub G, Heijmans M M P D, Sauren P and Berendse F 2011 What are the main climate drivers for shrub growth in Northeastern Siberian tundra? Biogeosciences 8 1169–79	2011	Asia	Russia	Shrub/woodland cover gain		
Brandt, J.S., Haynes, M.A., Kuemmerle, T., Waller, D.M. and Radeloff, V.C., 2013. Regime shift on the roof of the world: Alpine meadows converting to shrublands in the southern Himalayas. Biological Conservation. 158, 116-127.	2013	Asia	China	Shrub/woodland cover gain	1990	2009

Esper, J., & Schweingruber, F. H. (2004). Large-scale treeline changes recorded in Siberia. *Geophysical Research Letters*, *31*(6).	2004	Asia	Russia	Shrub/woodland cover gain		
Esper, J., & Schweingruber, F. H. (2004). Large-scale treeline changes recorded in Siberia. *Geophysical Research Letters*, *31*(6).	2004	Asia	Russia	Shrub/woodland cover gain		
Esper, J., & Schweingruber, F. H. (2004). Large-scale treeline changes recorded in Siberia. *Geophysical Research Letters*, *31*(6).	2004	Asia	Russia	Shrub/woodland cover gain		
Feng, Q., Jiang, X., Wang, X., and Cao, S. (2015). What has caused desetification in China? Nature Scientific Reports 5:15998.	2015	Asia	China	Grass cover loss	1983	2012
Feng, Q., Jiang, X., Wang, X., and Cao, S. (2015). What has caused desetification in China? Nature Scientific Reports 5:15998.	2015	Asia	China	Grass cover loss	1983	2012
Feng, Q., Jiang, X., Wang, X., and Cao, S. (2015). What has caused desetification in China? Nature Scientific Reports 5:15998.	2015	Asia	China	Grass cover loss	1983	2012
Feng, Q., Jiang, X., Wang, X., and Cao, S. (2015). What has caused desetification in China? Nature Scientific Reports 5:15998.	2015	Asia	China	Grass cover loss	1983	2012
Forbes B C, Fauria M M and Zetterberg P 2010 Russian arctic warming and 'greening' are closely tracked by tundra shrub willows Glob. Change Biol. 16 1542–54	2010	Asia	Russia	Shrub/woodland cover gain		
Gervais, B. R., & MacDonald, G. M. (2000). A 403-year record of July temperatures and treeline dynamics of Pinus sylvestris from the Kola Peninsula, northwest Russia. *Arctic, Antarctic, and Alpine Research*, *32*(3), 295-302.	2000	Asia	Russia	Forest cover gain		
Kudo, G., Amagai, Y., Hoshino, B., & Kaneko, M. (2011). Invasion of dwarf bamboo into alpine snow-meadows in northern Japan: pattern of expansion and impact on species diversity. Ecology and Evolution, 1(1), 85-96.	2011	Asia	Japan	Herbaceous cover gain	1977	2009
Li, Z., Chen, Y., Li, W., Deng, H., & Fang, G. (2015). Potential impacts of climate change on vegetation dynamics in Central Asia. Journal of Geophysical Research: Atmospheres, 120(24), 12345-12356.	2015	Asia	Central asia	Shrub/woodland cover gain	1980	2013
Liu, F., Zhang, H., Qin, Y., Dong, J., Xu, E., Yang. Y., Zhang, G., and Xiao, X. (2016). Semi-natural areas of Tarim Basin in northwest China: Linkage to desertification. Science of the Total Environment 573, 178-188.	2016	Asia	China	Grass cover loss	1990	2010
Mazepa, V. S. (2005). Stand density in the last millennium at the upper tree-line ecotone in the Polar Ural Mountains. *Canadian Journal of Forest Research*, *35*(9), 2082-2091.	2005	Asia	Russia	Forest cover gain		
Meshinev, T., Apostolova, I., & Koleva, E. (2000). Influence of warming on timberline rising: a case study on Pinus peuce Griseb. in Bulgaria. *Phytocoenologia*, *30*(3/4), 431-438.	2000	Asia	Bulgaria	Forest cover gain		

Moiseev, P. A. (2002). Effect of climatic changes on radial increment and age structure formation in high-mountain larch forests of the Kuznetsk Ala Tau. *Russian Journal of Ecology*, *33*(1), 7-13.	2002	Asia	Russia	Forest cover gain		
Puyravaud, J.P., Dufour, C. and Aravajy, S., 2003. Rain forest expansion mediated by successional processes in vegetation thickets in the Western Ghats of India. Journal of Biogeography. 30, 1067-1080.	2003	Asia	India	Shrub/woodland cover gain		
SHIYATOV, S. G. (2003). Rates of change in the upper treeline ecotone in the Polar Ural Mountains. *Nature*, *394*, 739-743.	2003	Asia	Russia	Forest cover gain	1910	2000
SHIYATOV, S. G. (2003). Rates of change in the upper treeline ecotone in the Polar Ural Mountains. *Nature*, *394*, 739-743.	2003	Asia	Russia	Forest cover gain	1910	2000
Shiyatov, S. G., Terent'Ev, M. M., & Fomin, V. V. (2005). Spatiotemporal dynamics of forest-tundra communities in the Polar Urals. *Russian Journal of Ecology*, *36*(2), 69-75.	2005	Asia	Russia	Forest cover gain	1910	2000
Shiyatov, S. G., Terent'Ev, M. M., & Fomin, V. V. (2005). Spatiotemporal dynamics of forest-tundra communities in the Polar Urals. *Russian Journal of Ecology*, *36*(2), 69-75.	2005	Asia	Russia	Forest cover gain	1910	2000
Shiyatov, S. G., Terent'ev, M. M., Fomin, V. V., & Zimmermann, N. E. (2007). Altitudinal and horizontal shifts of the upper boundaries of open and closed forests in the Polar Urals in the 20th century. *Russian Journal of Ecology*, *38*(4), 223-227.	2007	Asia	Russia	Forest cover gain	1910	2000
Shrestha, B. B., Ghimire, B., Lekhak, H. D., & Jha, P. K. (2007). Regeneration of treeline birch (Betula utilis D. Don) forest in a trans-Himalayan dry valley in central Nepal. *Mountain Research and Development*, *27*(3), 259-268.	2007	Asia	Nepal	Forest cover gain		
Zhang, D. 2019. China's forest expansion in the last three plus decades: Why and how? Forest Policy and Economics 98:75–81.	2019	Asia	China	Forest cover gain	1977	2013
Sigdel, S. R., Wang, Y., Camarero, J. J., Zhu, H., Liang, E., & Peñuelas, J. (2018). Moisture-mediated responsiveness of treeline shifts to global warming in the Himalayas. *Global change biology*, *24*(11), 5549-5559.	2018	Asia	Nepal	Forest cover gain	1865	2015
Sigdel, S. R., Wang, Y., Camarero, J. J., Zhu, H., Liang, E., & Peñuelas, J. (2018). Moisture-mediated responsiveness of treeline shifts to global warming in the Himalayas. *Global change biology*, *24*(11), 5549-5559.	2018	Asia	Nepal	Forest cover gain	1865	2015
Sigdel, S. R., Wang, Y., Camarero, J. J., Zhu, H., Liang, E., & Peñuelas, J. (2018). Moisture-mediated responsiveness of treeline shifts to global warming in the Himalayas. *Global change biology*, *24*(11), 5549-5559.	2018	Asia	Nepal	Forest cover gain	1865	2015

Sigdel, S. R., Wang, Y., Camarero, J. J., Zhu, H., Liang, E., & Peñuelas, J. (2018). Moisture-mediated responsiveness of treeline shifts to global warming in the Himalayas. *Global change biology*, *24*(11), 5549-5559.	2018	Asia	Nepal	Forest cover gain	1865	2015
Sigdel, S. R., Wang, Y., Camarero, J. J., Zhu, H., Liang, E., & Peñuelas, J. (2018). Moisture-mediated responsiveness of treeline shifts to global warming in the Himalayas. *Global change biology*, *24*(11), 5549-5559.	2018	Asia	Nepal	Forest cover gain	1865	2015
Sigdel, S. R., Wang, Y., Camarero, J. J., Zhu, H., Liang, E., & Peñuelas, J. (2018). Moisture-mediated responsiveness of treeline shifts to global warming in the Himalayas. *Global change biology*, *24*(11), 5549-5559.	2018	Asia	Nepal	Forest cover gain	1865	2015
Du, H., Liu, J., Li, M. H., Büntgen, U., Yang, Y., Wang, L., ... & He, H. S. (2018). Warming-induced upward migration of the alpine treeline in the Changbai Mountains, northeast China. *Global Change Biology*, *24*(3), 1256-1266.	2018	Asia	China	Forest cover gain		1890
Du, H., Liu, J., Li, M. H., Büntgen, U., Yang, Y., Wang, L., ... & He, H. S. (2018). Warming-induced upward migration of the alpine treeline in the Changbai Mountains, northeast China. *Global Change Biology*, *24*(3), 1256-1266.	2018	Asia	China	Forest cover gain	1891	1996
Du, H., Liu, J., Li, M. H., Büntgen, U., Yang, Y., Wang, L., ... & He, H. S. (2018). Warming-induced upward migration of the alpine treeline in the Changbai Mountains, northeast China. *Global Change Biology*, *24*(3), 1256-1266.	2018	Asia	China	Forest cover gain	1996	2005
Gatti, R. C., Callaghan, T., Velichevskaya, A., Dudko, A., Fabbio, L., Battipaglia, G., & Liang, J. (2019). Accelerating upward treeline shift in the Altai Mountains under last-century climate change. *Scientific reports*, *9*(1), 1-13.	2019	Asia	Russia	Forest cover gain	1950	2002
Piao, S., Yin, G., Tan, J., Cheng, L., Huang, M., Li, Y., ... & Poulter, B. (2015). Detection and attribution of vegetation greening trend in China over the last 30 years. *Global change biology*, *21*(4), 1601-1609.	2015	Asia	China	Forest cover gain	1982	2009
Piao, S., Yin, G., Tan, J., Cheng, L., Huang, M., Li, Y., ... & Poulter, B. (2015). Detection and attribution of vegetation greening trend in China over the last 30 years. *Global change biology*, *21*(4), 1601-1609.	2015	Asia	China	Forest cover gain	1982	2009
Salmon, V. G., A. L. Breen, J. Kumar, M. J. Lara, P. E. Thornton, S. D. Wullschleger, and C. M. Iversen. 2019. Alder Distribution and Expansion Across a Tundra Hillslope: Implications for Local N Cycling. Frontiers in Plant Science 10:1–15.	2019	North America	United States	Shrub/woodland cover gain	1956	2014
Joly, K., M. J. Cole, and R. R. Jandt. 2007. Diets of overwintering Caribou, rangifer tarandus, track decadal changes in Arctic Tundra vegetation. Canadian Field-Naturalist 121:379–383.	2007	North America	United States	Herbaceous cover gain	1981	2005

Terskaia, A., Dial, R. J., & Sullivan, P. F. (2020). Pathways of tundra encroachment by trees and tall shrubs in the western Brooks Range of Alaska. *Ecography*, *43*(5), 769-778.	2020	North America	United States	Shrub/woodland cover gain	1952	2015
Terskaia, A., Dial, R. J., & Sullivan, P. F. (2020). Pathways of tundra encroachment by trees and tall shrubs in the western Brooks Range of Alaska. *Ecography*, *43*(5), 769-778.	2020	North America	United States	Shrub/woodland cover gain	1952	2015
Terskaia, A., Dial, R. J., & Sullivan, P. F. (2020). Pathways of tundra encroachment by trees and tall shrubs in the western Brooks Range of Alaska. *Ecography*, *43*(5), 769-778.	2020	North America	United States	Forest cover gain	1952	2015
Lloyd, A. H., & Fastie, C. L. (2003). Recent changes in treeline forest distribution and structure in interior Alaska. *Ecoscience*, *10*(2), 176-185.	2003	North America	United States	Forest cover gain	1850	2002
Lloyd, A. H., & Fastie, C. L. (2003). Recent changes in treeline forest distribution and structure in interior Alaska. *Ecoscience*, *10*(2), 176-185.	2003	North America	United States	Forest cover gain	1850	2002
Lloyd, A. H. (2005). Ecological histories from Alaskan tree lines provide insight into future change. Ecology, 86(7), 1687-1695.	2005	North America	United States	Forest cover gain		
Lloyd, A. H. (2005). Ecological histories from Alaskan tree lines provide insight into future change. Ecology, 86(7), 1687-1695.	2005	North America	United States	Forest cover gain		
Villarreal, S., Hollister, R.D., Johnson, D.R., Lara, M.J., Webber, P.J. & Tweedie, C.E. (2012). Tundra vegetation change near Barrow, Alaska (19722010). *Environ. Res. Lett.*, 7.	2012	North America	United States	Shrub/woodland cover gain	1972	2010
Villarreal, S., Hollister, R.D., Johnson, D.R., Lara, M.J., Webber, P.J. & Tweedie, C.E. (2012). Tundra vegetation change near Barrow, Alaska (19722010). *Environ. Res. Lett.*, 7.	2012	North America	United States	Grass cover loss	1972	2010
Tape, K., Sturm, M. & Racine, C. (2006). The evidence for shrub expansion in Northern Alaska and the Pan-Arctic. *Glob. Chang. Biol.*, 12, 686–702.	2006	North America	United States	Shrub/woodland cover gain	1945	2002
Sturm, M., Racine, C.H. and Tape, K.D. (2001) Increasing shrub abundance in the Arctic. Nature 411,546–547.	2001	North America	USA	Forest cover gain	1950	2000
Sturm, M., Racine, C.H. and Tape, K.D. (2001) Increasing shrub abundance in the Arctic. Nature 411,546–547.	2001	North America	USA	Shrub/woodland cover gain	1950	2000
Duchesne, R. R., Chopping, M. J., Tape, K. D., Wang, Z., & Schaaf, C. L. B. (2018). Changes in tall shrub abundance on the North Slope of Alaska, 2000–2010. Remote Sensing of Environment, 219(December 2016), 221–232. https://doi.org/10.1016/j.rse.2018.10.013	2018	North America	United States	Shrub/woodland cover gain	2000	2010
Duchesne, R. R., Chopping, M. J., Tape, K. D., Wang, Z., & Schaaf, C. L. B. (2018). Changes in tall shrub abundance on the North Slope of Alaska, 2000–2010. Remote Sensing of Environment, 219(December 2016), 221–232. https://doi.org/10.1016/j.rse.2018.10.014	2018	North America	United States	Shrub/woodland cover gain	2000	2010

Duchesne, R. R., Chopping, M. J., Tape, K. D., Wang, Z., & Schaaf, C. L. B. (2018). Changes in tall shrub abundance on the North Slope of Alaska, 2000–2010. Remote Sensing of Environment, 219(December 2016), 221–232. https://doi.org/10.1016/j.rse.2018.10.015	2018	North America	United States	Shrub/woodland cover gain	2000	2010
Duchesne, R. R., Chopping, M. J., Tape, K. D., Wang, Z., & Schaaf, C. L. B. (2018). Changes in tall shrub abundance on the North Slope of Alaska, 2000–2010. Remote Sensing of Environment, 219(December 2016), 221–232. https://doi.org/10.1016/j.rse.2018.10.016	2018	North America	United States	Shrub/woodland cover gain	2000	2010
Duchesne, R. R., Chopping, M. J., Tape, K. D., Wang, Z., & Schaaf, C. L. B. (2018). Changes in tall shrub abundance on the North Slope of Alaska, 2000–2010. Remote Sensing of Environment, 219(December 2016), 221–232. https://doi.org/10.1016/j.rse.2018.10.017	2018	North America	United States	Shrub/woodland cover gain	2000	2010
Naito, A. T., and D. M. Cairns. 2015. Patterns of shrub expansion in Alaskan arctic river corridors suggest phase transition. Ecology and Evolution 5:87–101.	2015	North America	United States	Shrub/woodland cover gain	1950	2010
Lloyd, A. H., and C. L. Fastie. 2002. Spatial and temporal variability in the growth and climate response of tree line trees in Alaska. Climatic Change 52:481–509.	2002	North America	United States	Forest cover gain	1923	1996
Dial R J, Berg E E, Timm K, McMahon A and Geck J 2007 Changes in the alpine forest-tundra ecotone commensurate with recent warming in southcentral Alaska: evidence from orthophotos and field plots J. Geophys. Res. 112 G04015	2007	North America	USA	Shrub/woodland cover gain		
Berg, E.E., Hillman, K.M., Dial, R. and DeRuwe, A., 2009. Recent woody invasion of wetlands on the Kenai Peninsula Lowlands, south-central Alaska: a major regime shift after 18 000 years of wet Sphagnum–sedge peat recruitment. Canadian Journal of Forest Research. 39, 2033-2046.	2009	North America	Alaska	Shrub/woodland cover gain	1951	1998
Tape, K.D., Hallinger, M., Welker, J.M. & Ruess, R.W. (2012). Landscape Heterogeneity of Shrub Expansion in Arctic Alaska. *Ecosystems*, 15, 711–724.	2012	North America	United States	Shrub/woodland cover gain	1950	2006
Brodie, J. F., C. A. Roland, S. E. Stehn, and E. Smirnova. 2019. Variability in the expansion of trees and shrubs in boreal Alaska. Ecology 100:1–10.	2019	North America	United States	Forest cover gain	1906	2016
Knapp, A. K., Briggs, J. M., Collins, S. L., Archer, S. R., BRET-HARTE, M. S., Ewers, B. E., ... & Cleary, M. B. (2008). Shrub encroachment in North American grasslands: shifts in growth form dominance rapidly alters control of ecosystem carbon inputs. Global Change Biology, 14(3), 615-623.	2008	North America	United States	Shrub/woodland cover gain		
Beck, P.S.A., Juday, G.P., Alix, C., Barber, V.A., Winslow, S.E., Sousa, E.E., Heiser, P., Herriges, J.D., & Goetz, S.J. 2011. Changes in forest productivity across Alaska consistent with biome shift. Ecology Letters, 14:373-379.	2011	North America	United States	Forest cover gain	1982	2008

Myers-Smith, I.H., Forbes, B.C., Wilmking, M., Hallinger, M., Lantz, T., Blok, D., Tape, K.D., Macias-Fauria, M., Sass-Klaassen, U., & Lévesque, E. (2011). Shrub expansion in tundra ecosystems: dynamics, impacts and research priorities. Environmental Research Letters, 6(4), 1-15.	2011	North America	USA	Shrub/woodland cover gain	~50 yr	
Lloyd, A. H. (2005). Ecological histories from Alaskan tree lines provide insight into future change. Ecology, 86(7), 1687-1695.	2005	North America	United States	Forest cover gain		
Wang, J. A., Sulla-Menashe, D., Woodcock, C. E., Sonnentag, O., Keeling, R. F., & Friedl, M. A. (2020). Extensive land cover change across Arctic–Boreal Northwestern North America from disturbance and climate forcing. Global Change Biology, 26(2), 807-822.	2020	North America	USA	Herbaceous cover gain	1984	2014
Wang, J. A., Sulla-Menashe, D., Woodcock, C. E., Sonnentag, O., Keeling, R. F., & Friedl, M. A. (2020). Extensive land cover change across Arctic–Boreal Northwestern North America from disturbance and climate forcing. Global Change Biology, 26(2), 807-822.	2020	North America	USA	Forest type change	1984	2014
Wang, J. A., Sulla-Menashe, D., Woodcock, C. E., Sonnentag, O., Keeling, R. F., & Friedl, M. A. (2020). Extensive land cover change across Arctic–Boreal Northwestern North America from disturbance and climate forcing. Global Change Biology, 26(2), 807-822.	2020	North America	USA	Shrub/woodland cover gain	1984	2014
Myers-Smith I H, Hik D S, Kennedy C, Cooley D, Johnstone J F, Kenney A J and Krebs C J 2011 Expansion of canopy-forming willows over the twentieth century on Herschel Island, Yukon Territory, Canada Ambio 40 610–23	2011	North America	Canada	Shrub/woodland cover gain		
Myers-Smith I H 2011 Shrub encroachment in arctic and alpine tundra: mechanisms of expansion and ecosystem impacts PhD thesis University of Alberta	2011	North America	Canada	Shrub/woodland cover gain		
Myers-Smith, I. H., and D. S. Hik. 2018. Climate warming as a driver of tundra shrubline advance. Journal of Ecology 106:547–560.	2018	North America	Canada	Shrub/woodland cover gain	2009	2013
Lantz, T. C., P. Marsh, and S. V. Kokelj. 2013. Recent Shrub Proliferation in the Mackenzie Delta Uplands and Microclimatic Implications. Ecosystems 16:47–59.	2013	North America	Canada	Shrub/woodland cover gain	1972	2004
Wang, J. A., Sulla-Menashe, D., Woodcock, C. E., Sonnentag, O., Keeling, R. F., & Friedl, M. A. (2020). Extensive land cover change across Arctic–Boreal Northwestern North America from disturbance and climate forcing. Global Change Biology, 26(2), 807-822.	2020	North America	Canada/Alaska	Shrub/woodland cover gain	1984	2014
Wang, J. A., Sulla-Menashe, D., Woodcock, C. E., Sonnentag, O., Keeling, R. F., & Friedl, M. A. (2020). Extensive land cover change across Arctic–Boreal Northwestern North America from disturbance and climate forcing. Global Change Biology, 26(2), 807-822.	2020	North America	Canada/Alaska	Forest type change	1984	2014

Jackson, M. M., Topp, E., Gergel, S. E., Martin, K., Pirotti, F., & Sitzia, T. (2016). Expansion of subalpine woody vegetation over 40 years on Vancouver Island, British Columbia, Canada. *Canadian Journal of Forest Research*, *46*(3), 437-443.	2016	North America	Canada	Forest cover gain	1962	2005
Jackson, M. M., Topp, E., Gergel, S. E., Martin, K., Pirotti, F., & Sitzia, T. (2016). Expansion of subalpine woody vegetation over 40 years on Vancouver Island, British Columbia, Canada. Canadian Journal of Forest Research, 46(3), 437-443.	2016	North America	Canada	Shrub/woodl and cover gain	1962	2005
Jackson, M. M., Topp, E., Gergel, S. E., Martin, K., Pirotti, F., & Sitzia, T. (2016). Expansion of subalpine woody vegetation over 40 years on Vancouver Island, British Columbia, Canada. Canadian Journal of Forest Research, 46(3), 437-443.	2016	North America	Canada	Shrub/woodl and cover gain	1962	2005
Mackay J R and Burn C R 2011 A century (1910–2008) of change in a collapsing pingo, Parry Peninsula, Western Arctic Coast, Canada Permafr. Periglac. 22 266–72	2011	North America	Canada	Shrub/woodl and cover gain		
Jackson, M. M., Topp, E., Gergel, S. E., Martin, K., Pirotti, F., & Sitzia, T. (2016). Expansion of subalpine woody vegetation over 40 years on Vancouver Island, British Columbia, Canada. Canadian Journal of Forest Research, 46(3), 437-443.	2016	North America	Canada	Forest cover gain	1962	2005
Laroque, C. P., Lewis, D. H., & Smith, D. J. (2000). Treeline dynamics on southern Vancouver Island, British Columbia. Western Geography, 10(11), 43-63.	2000	North America	Canada	Forest cover gain		
Laroque, C. P., Lewis, D. H., & Smith, D. J. (2000). Treeline dynamics on southern Vancouver Island, British Columbia. Western Geography, 10(11), 43-63.	2000	North America	Canada	Forest cover gain		
Zald, H.S., 2008. Extent and spatial patterns of grass bald land cover change (1948–2000), Oregon Coast Range, USA. In Herbaceous Plant Ecology (pp. 153-165). Springer, Dordrecht.	2008	North America	United States	Forest cover gain	1948	2000
Bai, Y., Broersma, K., Thompson, D. and Ross, T.J., 2004. Landscape-level dynamics of grassland-forest transitions in British Columbia. Journal of Range Management. 66-75.	2004	North America	British Colombia of Canada	Forest cover gain	1960	1990
Miller, E.A. and Halpern, C.B., 1998. Effects of environment and grazing disturbance on tree establishment in meadows of the central Cascade Range, Oregon, USA. Journal of Vegetation Science, 9(2), pp.265-282.	1998	North America	United States	Forest cover gain	1983	1993
Takaoka, S. and Swanson, F.J., 2008. Change in extent of meadows and shrub fields in the central western Cascade Range, Oregon. The Professional Geographer. 60, 527-540.	2008	North America	USA	Forest cover gain	1946	2000
Taylor, A.H., 1995. Forest expansion and climate change in the mountain hemlock (Tsuga mertensiana) zone, Lassen Volcanic National Park, California, USA. Arctic and alpine Research. 27, 207-216.	1995	North America	United States	Forest cover gain	1842	1990

Barger, N. N., Archer, S. R., Campbell, J. L., Huang, C. Y., Morton, J. A., & Knapp, A. K. (2011). Woody plant proliferation in North American drylands: a synthesis of impacts on ecosystem carbon balance. Journal of Geophysical Research: Biogeosciences, 116(G4).	2011	North America	United States	Shrub/woodland cover gain	1951	1994
Miller, R.F. & Rose, J.A. (1999). Fire history and western Juniper encroachment in sagebrush steppe. Journal of Range Management, 52(6), 550-559.	1999	North America	United States	Shrub/woodland cover gain	1875	1995
Di Orio, A.P., Callas, R. and Schaefer, R.J., 2005. Forty-eight year decline and fragmentation of aspen (Populus tremuloides) in the South Warner Mountains of California. Forest Ecology and Management. 206,307-313.	2005	North America	United States	Forest/woodland decline	1946	1994
Millar, C.I., Westfall, R.D. and Delany, D.L., 2007. Response of high-elevation limber pine (Pinus flexilis) to multiyear droughts and 20th-century warming, Sierra Nevada, California, USA. Canadian Journal of Forest Research, 37(12), pp.2508-2520.	2007	North America	Unites States	Forest/woodland decline	1985	1995
McIntyre, P. J., Thorne, J. H., Dolanc, C. R., Flint, A. L., Flint, L. E., Kelly, M., & Ackerly, D. D. (2015). Twentieth-century shifts in forest structure in California: Denser forests, smaller trees, and increased dominance of oaks. Proceedings of the National Academy of Sciences, 112(5), 1458-1463.	2015	North America	United States	Forest cover gain	1930	2000
McIntyre, P. J., Thorne, J. H., Dolanc, C. R., Flint, A. L., Flint, L. E., Kelly, M., & Ackerly, D. D. (2015). Twentieth-century shifts in forest structure in California: Denser forests, smaller trees, and increased dominance of oaks. Proceedings of the National Academy of Sciences, 112(5), 1458-1463.	2015	North America	United States	Forest type change	1930	2000
Lubetkin, K. C., Westerling, A. L., & Kueppers, L. M. (2017). Climate and landscape drive the pace and pattern of conifer encroachment into subalpine meadows. *Ecological Applications*, *27*(6), 1876-1887.	2017	North America	United States	Forest cover gain	1920	2013
Guarín, A. and Taylor, A.H., 2005. Drought triggered tree mortality in mixed conifer forests in Yosemite National Park, California, USA. Forest ecology and management, 218(1-3), pp.229-244.	2005	North America	Unites States	Forest/woodland decline	1986	1992
Van Mantgem, P.J. and Stephenson, N.L., 2007. Apparent climatically induced increase of tree mortality rates in a temperate forest. Ecology Letters, 10(10), pp.909-916.	2007	North America	United States	Forest/woodland decline	1983	2004
McIntyre, P. J., Thorne, J. H., Dolanc, C. R., Flint, A. L., Flint, L. E., Kelly, M., & Ackerly, D. D. (2015). Twentieth-century shifts in forest structure in California: Denser forests, smaller trees, and increased dominance of oaks. Proceedings of the National Academy of Sciences, 112(5), 1458-1463.	2015	North America	United States	Forest cover gain	1930	2000

McIntyre, P. J., Thorne, J. H., Dolanc, C. R., Flint, A. L., Flint, L. E., Kelly, M., & Ackerly, D. D. (2015). Twentieth-century shifts in forest structure in California: Denser forests, smaller trees, and increased dominance of oaks. Proceedings of the National Academy of Sciences, 112(5), 1458-1463.	2015	North America	United States	Forest type change	1930	2000
Millar, C. I., Westfall, R. D., Delany, D. L., King, J. C., & Graumlich, L. J. (2004). Response of subalpine conifers in the Sierra Nevada, California, USA, to 20th-century warming and decadal climate variability. Arctic, Antarctic, and Alpine Research, 36(2), 181-200.	2004	North America	United States	Forest cover gain	1945	1976
Millar, C. I., Westfall, R. D., Delany, D. L., King, J. C., & Graumlich, L. J. (2004). Response of subalpine conifers in the Sierra Nevada, California, USA, to 20th-century warming and decadal climate variability. Arctic, Antarctic, and Alpine Research, 36(2), 181-200.	2004	North America	United States	Forest cover gain	1920	1945
Millar, C. I., Westfall, R. D., Delany, D. L., King, J. C., & Graumlich, L. J. (2004). Response of subalpine conifers in the Sierra Nevada, California, USA, to 20th-century warming and decadal climate variability. Arctic, Antarctic, and Alpine Research, 36(2), 181-200.	2004	North America	United States	Forest cover gain	1980	2002
Millar, C. I., Westfall, R. D., Delany, D. L., King, J. C., & Graumlich, L. J. (2004). Response of subalpine conifers in the Sierra Nevada, California, USA, to 20th-century warming and decadal climate variability. Arctic, Antarctic, and Alpine Research, 36(2), 181-200.	2004	North America	United States	Forest cover gain	1900	2002
Ferrell, G.T., Otrosina, W.J. and DeMars, C.J., 1994. Predicting susceptibility of white fir during a drought-associated outbreak of the fir engraver, Scolytus centralis, in California. Can. J. For. Res. 24: 301-305.	1994	North America	Unites States	Forest/woodland decline	1986	1992
Macomber, S.A. and Woodcock, C.E., 1994. Mapping and monitoring conifer mortality using remote sensing in the Lake Tahoe Basin. Remote sensing of environment, 50(3), pp.255-266.	1994	North America	Unites States	Forest/woodland decline	1986	1992
Morris, C., Badik, K.J., Morris, L.R., and Weltz, M.A. (2016). Integrating precipitation, grazing, past effects and interactions in longterm vegetation change. Journal of Arid Environments, 124, 111-117.	2016	North America	United States	Herbaceous cover gain	1969	2011
Syphard, A. D., T. J. Brennan, and J. E. Keeley. 2019. Drivers of chaparral type conversion to herbaceous vegetation in coastal Southern California. Diversity and Distributions 25: 90– 101.	2018	North America	United States	Herbaceous cover gain	1943	2014
Miller, R.F. & Rose, J.A. (1995). Historic expansion of Juniperus occidentalis (western juniper) in southeastern Oregon. The Great Basin Naturalist, 55(1), 37-45.	1995	North America	United States	Shrub/woodland cover gain	1880	1985

Barger, N. N., Archer, S. R., Campbell, J. L., Huang, C. Y., Morton, J. A., & Knapp, A. K. (2011). Woody plant proliferation in North American drylands: a synthesis of impacts on ecosystem carbon balance. Journal of Geophysical Research: Biogeosciences, 116(G4).	2011	North America	United States	Shrub/woodland cover gain	1881	1990
Park, I. W., Hooper, J., Flegal, J. M., & Jenerette, G. D. (2018). Impacts of climate, disturbance and topography on distribution of herbaceous cover in Southern California chaparral: Insights from a remote-sensing method. Diversity and Distributions, 24(4), 497-508.	2018	North America	United States	Herbaceous cover gain		2008
Köchy, M. and Wilson, S.D., 2001. Nitrogen deposition and forest expansion in the northern Great Plains. Journal of Ecology. 89, 807-817.	2001	North America	Canada	Shrub/woodland cover gain	1930	1995
Van Mantgem, P.J., Stephenson, N.L., Byrne, J.C., Daniels, L.D., Franklin, J.F., Fulé, P.Z., Harmon, M.E., Larson, A.J., Smith, J.M., Taylor, A.H. and Veblen, T.T., 2009. Widespread increase of tree mortality rates in the western United States. Science, 323(5913), pp.521-524.	2009	North America	United States	Forest/woodland decline	1955	2007
Burkhardt, J.W., & Tisdale, E.W. (1976). Causes of Juniper invasion in southwest Idaho. Ecology, 57(3), 472-484.	1976	North America	United States	Shrub/woodland cover gain	1870	1970
McIntyre, P. J., Thorne, J. H., Dolanc, C. R., Flint, A. L., Flint, L. E., Kelly, M., & Ackerly, D. D. (2015). Twentieth-century shifts in forest structure in California: Denser forests, smaller trees, and increased dominance of oaks. Proceedings of the National Academy of Sciences, 112(5), 1458-1463.	2015	North America	United States	Forest cover gain	1930	2000
McIntyre, P. J., Thorne, J. H., Dolanc, C. R., Flint, A. L., Flint, L. E., Kelly, M., & Ackerly, D. D. (2015). Twentieth-century shifts in forest structure in California: Denser forests, smaller trees, and increased dominance of oaks. Proceedings of the National Academy of Sciences, 112(5), 1458-1463.	2015	North America	United States	Forest type change	1930	2000
Smithers, B. V., North, M. P., Millar, C. I., & Latimer, A. M. (2018). Leap frog in slow motion: Divergent responses of tree species and life stages to climatic warming in Great Basin subalpine forests. *Global Change Biology*, *24*(2), e442-e457.	2018	North America	United States	Forest cover gain	1950	2016
Luckman 1990	1990	North America	Canada	Forest cover gain		
Savage, M., 1997. The role of anthropogenic influences in a mixed-conifer forest mortality episode. Journal of Vegetation Science, 8(1), pp.95-104.	1997	North America	Unites States and Mexico	Forest/woodland decline	1984	early 1990s
McIntyre, P. J., Thorne, J. H., Dolanc, C. R., Flint, A. L., Flint, L. E., Kelly, M., & Ackerly, D. D. (2015). Twentieth-century shifts in forest structure in California: Denser forests, smaller trees, and increased dominance of oaks. Proceedings of the National Academy of Sciences, 112(5), 1458-1463.	2015	North America	United States	Forest cover gain	1930	2000

McIntyre, P. J., Thorne, J. H., Dolanc, C. R., Flint, A. L., Flint, L. E., Kelly, M., & Ackerly, D. D. (2015). Twentieth-century shifts in forest structure in California: Denser forests, smaller trees, and increased dominance of oaks. Proceedings of the National Academy of Sciences, 112(5), 1458-1463.	2015	North America	United States	Forest type change	1930	2000
Bekker, M.F., 2005. Positive feedback between tree establishment and patterns of subalpine forest advancement, Glacier National Park, Montana, USA. Arctic, Antarctic, and Alpine Research. 37, 97-107.	2005	North America	United States	Shrub/woodland cover gain	1730	2004
Blackburn, W.H., & Tueller, P.T. (1970). Pinyon and juniper invasion in black sagebrush communities in east-central Nevada. Ecology, 51(5), 841-848.	1970	North America	United States	Forest cover gain	1720	1960
Köchy, M. and Wilson, S.D., 2001. Nitrogen deposition and forest expansion in the northern Great Plains. Journal of Ecology. 89, 807-817.	2001	North America	Canada	Shrub/woodland cover gain	1930	1995
Köchy, M. and Wilson, S.D., 2001. Nitrogen deposition and forest expansion in the northern Great Plains. Journal of Ecology. 89, 807-817.	2001	North America	Canada	Shrub/woodland cover gain	1930	1995
Mast, J. N., & Wolf, J. J. (2004). Ecotonal changes and altered tree spatial patterns in lower mixed-conifer forests, Grand Canyon National Park, Arizona, USA. *Landscape Ecology*, *19*(2), 167-180.	2004	North America	United States	Forest cover gain	1860	2000
Sankey, T.T. and Germino, M.J., 2008. Assessment of juniper encroachment with the use of satellite imagery and geospatial data. Rangeland Ecology & Management. 61, 412-418.	2008	North America	United States	Shrub/woodland cover gain	1985	2005
Arno, S. F., & Gruell, G. E. (1986). Douglas-fir encroachment into mountain grasslands in southwestern Montana. *Journal of Range Management*, 272-276.	1986	North America	United States	Forest cover gain	1700	1980
Briggs, J.M., Schaafsma, H. and Trenkov, D., 2007. Woody vegetation expansion in a desert grassland: Prehistoric human impact?. Journal of Arid Environments, 69(3), pp.458-472.	2007	North America	United States	Shrub/woodland cover gain	1940	2001
Barger, N. N., Archer, S. R., Campbell, J. L., Huang, C. Y., Morton, J. A., & Knapp, A. K. (2011). Woody plant proliferation in North American drylands: a synthesis of impacts on ecosystem carbon balance. Journal of Geophysical Research: Biogeosciences, 116(G4).	2011	North America	United States	Shrub/woodland cover gain	1940	2001
Gitlin, A.R., Sthultz, C.M., Bowker, M.A., Stumpf, S., Paxton, K.L., Kennedy, K., Muñoz, A., Bailey, J.K. and Whitham, T.G., 2006. Mortality gradients within and among dominant plant populations as barometers of ecosystem change during extreme drought. Conservation Biology, 20(5), pp.1477-1486.	2006	North America	United States	Forest/woodland decline	2000	2004
Gitlin, A.R., Sthultz, C.M., Bowker, M.A., Stumpf, S., Paxton, K.L., Kennedy, K., Muñoz, A., Bailey, J.K. and Whitham, T.G., 2006. Mortality gradients within and among dominant plant populations as barometers of ecosystem change during extreme drought. Conservation Biology, 20(5), pp.1477-1486.	2006	North America	United States	Forest/woodland decline	2000	2004

Gitlin, A.R., Sthultz, C.M., Bowker, M.A., Stumpf, S., Paxton, K.L., Kennedy, K., Muñoz, A., Bailey, J.K. and Whitham, T.G., 2006. Mortality gradients within and among dominant plant populations as barometers of ecosystem change during extreme drought. Conservation Biology, 20(5), pp.1477-1486.	2006	North America	United States	Forest/woodland decline	2000	2004
Gitlin, A.R., Sthultz, C.M., Bowker, M.A., Stumpf, S., Paxton, K.L., Kennedy, K., Muñoz, A., Bailey, J.K. and Whitham, T.G., 2006. Mortality gradients within and among dominant plant populations as barometers of ecosystem change during extreme drought. Conservation Biology, 20(5), pp.1477-1486.	2006	North America	United States	Forest/woodland decline	2000	2004
Gitlin, A.R., Sthultz, C.M., Bowker, M.A., Stumpf, S., Paxton, K.L., Kennedy, K., Muñoz, A., Bailey, J.K. and Whitham, T.G., 2006. Mortality gradients within and among dominant plant populations as barometers of ecosystem change during extreme drought. Conservation Biology, 20(5), pp.1477-1486.	2006	North America	United States	Forest/woodland decline	2000	2004
Gitlin, A.R., Sthultz, C.M., Bowker, M.A., Stumpf, S., Paxton, K.L., Kennedy, K., Muñoz, A., Bailey, J.K. and Whitham, T.G., 2006. Mortality gradients within and among dominant plant populations as barometers of ecosystem change during extreme drought. Conservation Biology, 20(5), pp.1477-1486.	2006	North America	United States	Forest/woodland decline	2000	2004
Myers-Smith, I.H., Forbes, B.C., Wilmking, M., Hallinger, M., Lantz, T., Blok, D., Tape, K.D., Macias-Fauria, M., Sass-Klaassen, U., & Lévesque, E. (2011). Shrub expansion in tundra ecosystems: dynamics, impacts and research priorities. Environmental Research Letters, 6(4), 1-15.	2011	North America	Canada	Shrub/woodland cover gain	2006	2011
Andruko, R., Danby, R., & Grogan, P. (2020). Recent Growth and Expansion of Birch Shrubs Across a Low Arctic Landscape in Continental Canada: Are These Responses More a Consequence of the Severely Declining Caribou Herd than of Climate Warming? Ecosystems. https://doi.org/10.1007/s10021-019-00474-7	2020	North America	Canada	Shrub/woodland cover gain	2006	2016
Mueller, R.C., Scudder, C.M., Porter, M.E., Talbot Trotter III, R., Gehring, C.A. and Whitham, T.G., 2005. Differential tree mortality in response to severe drought: evidence for long-term vegetation shifts. Journal of Ecology, 93(6), pp.1085-1093.	2005	North America	Unites States	Forest/woodland decline	1996	1996
Barger, N. N., Archer, S. R., Campbell, J. L., Huang, C. Y., Morton, J. A., & Knapp, A. K. (2011). Woody plant proliferation in North American drylands: a synthesis of impacts on ecosystem carbon balance. Journal of Geophysical Research: Biogeosciences, 116(G4).	2011	North America	United States	Shrub/woodland cover gain	1946	1998
Barger, N. N., Archer, S. R., Campbell, J. L., Huang, C. Y., Morton, J. A., & Knapp, A. K. (2011). Woody plant proliferation in North American drylands: a synthesis of impacts on ecosystem carbon balance. Journal of Geophysical Research: Biogeosciences, 116(G4).	2011	North America	United States	Shrub/woodland cover gain	1960	2000

McClaran, M. P. 2003. A century of vegetation change on the Santa Rita Experimental Range. Pages 16–33 in Santa Rita Experimental Range: one-hundred years (1903–2003) of accomplishments and contributions. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Tucson, Arizona, USA.	2003	North America	USA	Shrub/woodland cover gain	1960	2000
Barger, N. N., Archer, S. R., Campbell, J. L., Huang, C. Y., Morton, J. A., & Knapp, A. K. (2011). Woody plant proliferation in North American drylands: a synthesis of impacts on ecosystem carbon balance. Journal of Geophysical Research: Biogeosciences, 116(G4).	2011	North America	United States	Shrub/woodland cover gain	1936	1966
Barger, N. N., Archer, S. R., Campbell, J. L., Huang, C. Y., Morton, J. A., & Knapp, A. K. (2011). Woody plant proliferation in North American drylands: a synthesis of impacts on ecosystem carbon balance. Journal of Geophysical Research: Biogeosciences, 116(G4).	2011	North America	United States	Shrub/woodland cover gain	1966	1996
Brown, A.L., 1950. Shrub invasion of southern Arizona desert grassland. Journal of Range Management, 3(3), 172-177.	1950	North America	USA	Herbaceous cover gain	1931	1949
Donato, Daniel C., Brian J. Harvey, and Monica G. Turner. "Regeneration of montane forests 24 years after the 1988 Yellowstone fires: A fire-catalyzed shift in lower treelines?." *Ecosphere* 7.8 (2016): e01410.	2016	North America	United States	Herbaceous cover gain	1988	2012
Donato, Daniel C., Brian J. Harvey, and Monica G. Turner. "Regeneration of montane forests 24 years after the 1988 Yellowstone fires: A fire-catalyzed shift in lower treelines?." *Ecosphere* 7.8 (2016): e01410.	2016	North America	United States	Forest cover gain	1988	2012
Barger, N. N., Archer, S. R., Campbell, J. L., Huang, C. Y., Morton, J. A., & Knapp, A. K. (2011). Woody plant proliferation in North American drylands: a synthesis of impacts on ecosystem carbon balance. Journal of Geophysical Research: Biogeosciences, 116(G4).	2011	North America	United States	Shrub/woodland cover gain	1967	2005
Maher, E. L., & Germino, M. J. (2006). Microsite differentiation among conifer species during seedling establishment at alpine treeline. *Ecoscience*, *13*(3), 334-341.	2006	North America	United States	Forest cover gain		
Maher, E. L., & Germino, M. J. (2006). Microsite differentiation among conifer species during seedling establishment at alpine treeline. *Ecoscience*, *13*(3), 334-341.	2006	North America	United States	Forest cover gain		
Worrall, J.J., Egeland, L., Eager, T., Mask, R.A., Johnson, E.W., Kemp, P.A. and Shepperd, W.D., 2008. Rapid mortality of Populus tremuloides in southwestern Colorado, USA. Forest Ecology and Management, 255(3-4), pp.686-696.	2008	North America	United States	Forest/woodland decline	2005	2006
Köchy, M. and Wilson, S.D., 2001. Nitrogen deposition and forest expansion in the northern Great Plains. Journal of Ecology. 89, 807-817.	2001	North America	Canada	Shrub/woodland cover gain	1930	1995

Knapp, A. K., Briggs, J. M., Collins, S. L., Archer, S. R., BRET-HARTE, M. S., Ewers, B. E., ... & Cleary, M. B. (2008). Shrub encroachment in North American grasslands: shifts in growth form dominance rapidly alters control of ecosystem carbon inputs. Global Change Biology, 14(3), 615-623.	2008	North America	United States	Shrub/woodl and cover gain		
Knapp, A. K., Briggs, J. M., Collins, S. L., Archer, S. R., BRET-HARTE, M. S., Ewers, B. E., ... & Cleary, M. B. (2008). Shrub encroachment in North American grasslands: shifts in growth form dominance rapidly alters control of ecosystem carbon inputs. Global Change Biology, 14(3), 615-623.	2008	North America	United States	Shrub/woodl and cover gain		
Barger, N. N., Archer, S. R., Campbell, J. L., Huang, C. Y., Morton, J. A., & Knapp, A. K. (2011). Woody plant proliferation in North American drylands: a synthesis of impacts on ecosystem carbon balance. Journal of Geophysical Research: Biogeosciences, 116(G4).	2011	North America	United States	Shrub/woodl and cover gain	1936	1983
Hennessy et al 1983	1983	North America	USA	Shrub/woodl and cover gain	1937	1996
Knapp 2008	2008	North America	USA	Shrub/woodl and cover gain	1937	1996
Laliberte, A.S., Rango, A., Havstad, K.M., Paris, J.F., Beck, R.F., McNeely, R., Gonzalez, A.L. 2004. Object-oriented image analysis for mapping shrub encroachment from 1937 to 2003 in southern New Mexico. Remote Sensing of Environment, 93(1-2):198-210	2004	North America	USA	Shrub/woodl and cover gain	1937	2003
Knapp, A. K., Briggs, J. M., Collins, S. L., Archer, S. R., BRET-HARTE, M. S., Ewers, B. E., ... & Cleary, M. B. (2008). Shrub encroachment in North American grasslands: shifts in growth form dominance rapidly alters control of ecosystem carbon inputs. Global Change Biology, 14(3), 615-623.	2008	North America	United States	Shrub/woodl and cover gain		
Barger, N. N., Archer, S. R., Campbell, J. L., Huang, C. Y., Morton, J. A., & Knapp, A. K. (2011). Woody plant proliferation in North American drylands: a synthesis of impacts on ecosystem carbon balance. Journal of Geophysical Research: Biogeosciences, 116(G4).	2011	North America	United States	Shrub/woodl and cover gain	1937	2003
Barger, N. N., Archer, S. R., Campbell, J. L., Huang, C. Y., Morton, J. A., & Knapp, A. K. (2011). Woody plant proliferation in North American drylands: a synthesis of impacts on ecosystem carbon balance. Journal of Geophysical Research: Biogeosciences, 116(G4).	2011	North America	United States	Forest cover gain	1935	1996
Collins, S.L. and Xia, Y., 2014. Long-term dynamics and hotspots of change in a desert grassland plant community. The American Naturalist, 185(2), pp.E30-E43.	2014	North America	United States	Herbaceous cover gain	1989	2008

Allen, C.D., & Breshears, D.D. 1998. Drought-induced shift of a forest–woodland ecotone: Rapid landscape response to climate variation. Proceedings of the National Academy of Science **95**, 14839-14842.	1998	North America	United States	Shrub/woodland cover gain	1935	1975
Zier, J. L., & Baker, W. L. (2006). A century of vegetation change in the San Juan Mountains, Colorado: an analysis using repeat photography. *Forest Ecology and Management*, *228*(1-3), 251-262.	2006	North America	United States	Forest cover gain		
Zier, J. L., & Baker, W. L. (2006). A century of vegetation change in the San Juan Mountains, Colorado: an analysis using repeat photography. *Forest Ecology and Management*, *228*(1-3), 251-262.	2006	North America	United States	Forest cover gain		
Zier, J. L., & Baker, W. L. (2006). A century of vegetation change in the San Juan Mountains, Colorado: an analysis using repeat photography. *Forest Ecology and Management*, *228*(1-3), 251-262.	2006	North America	United States	Forest cover gain		
Barger, N. N., Archer, S. R., Campbell, J. L., Huang, C. Y., Morton, J. A., & Knapp, A. K. (2011). Woody plant proliferation in North American drylands: a synthesis of impacts on ecosystem carbon balance. Journal of Geophysical Research: Biogeosciences, 116(G4).	2011	North America	United States	Shrub/woodland cover gain	1960	1990
Barger, N. N., Archer, S. R., Campbell, J. L., Huang, C. Y., Morton, J. A., & Knapp, A. K. (2011). Woody plant proliferation in North American drylands: a synthesis of impacts on ecosystem carbon balance. Journal of Geophysical Research: Biogeosciences, 116(G4).	2011	North America	United States	Forest cover gain	1870	2006
Barger, N. N., Archer, S. R., Campbell, J. L., Huang, C. Y., Morton, J. A., & Knapp, A. K. (2011). Woody plant proliferation in North American drylands: a synthesis of impacts on ecosystem carbon balance. Journal of Geophysical Research: Biogeosciences, 116(G4).	2011	North America	United States	Forest cover gain	1930	1995
Dyer, J.M., & Moffett, K.E. (1999). Meadow invasion from high-elevation spruce-fir forest in south-central New Mexico. The Southwestern Naturalist, 44(4), 444-456.	1999	North America	United States	Forest cover gain	1936	1994
Formica, A., E. C. Farrer, I. W. Ashton, and K. N. Suding. 2014. Shrub expansion over the past 62 years in Rocky Mountain alpine tundra: Possible causes and consequences. Arctic, Antarctic, and Alpine Research 46:616–631.	2014	North America	United States	Shrub/woodland cover gain	1946	2008
Bock, J.H. & Bock, C.E. (1984). Effect of fires on woody vegetation in the pine-grassland ecotone of the Southern Black Hills. The American Midland Naturalist, 112(1), 35-42.	1984	North America	United States	Forest/woodland decline	1979	1981
Barger, N. N., Archer, S. R., Campbell, J. L., Huang, C. Y., Morton, J. A., & Knapp, A. K. (2011). Woody plant proliferation in North American drylands: a synthesis of impacts on ecosystem carbon balance. Journal of Geophysical Research: Biogeosciences, 116(G4).	2011	North America	United States	Shrub/woodland cover gain	1960	1983

Barger, N. N., Archer, S. R., Campbell, J. L., Huang, C. Y., Morton, J. A., & Knapp, A. K. (2011). Woody plant proliferation in North American drylands: a synthesis of impacts on ecosystem carbon balance. Journal of Geophysical Research: Biogeosciences, 116(G4).	2011	North America	United States	Shrub/woodland cover gain	1960	1983
Köchy, M. and Wilson, S.D., 2001. Nitrogen deposition and forest expansion in the northern Great Plains. Journal of Ecology. 89, 807-817.	2001	North America	Canada	Shrub/woodland cover gain	1930	1995
Ansley, R.J., Wu, X.B. and Kramp, B.A. (2001). Observation: Long-Term Increases in Mesquite Canopy Cover in a North Texas Savanna. Journal of Range Management, 54(2), 171-176.	2001	North America	USA	Shrub/woodland cover gain	1976	1995
Barger, N. N., Archer, S. R., Campbell, J. L., Huang, C. Y., Morton, J. A., & Knapp, A. K. (2011). Woody plant proliferation in North American drylands: a synthesis of impacts on ecosystem carbon balance. Journal of Geophysical Research: Biogeosciences, 116(G4).	2011	North America	United States	Shrub/woodland cover gain	1976	1995
Barger, N. N., Archer, S. R., Campbell, J. L., Huang, C. Y., Morton, J. A., & Knapp, A. K. (2011). Woody plant proliferation in North American drylands: a synthesis of impacts on ecosystem carbon balance. Journal of Geophysical Research: Biogeosciences, 116(G4).	2011	North America	United States	Shrub/woodland cover gain	1937	1999
Knapp, A. K., Briggs, J. M., Collins, S. L., Archer, S. R., BRET-HARTE, M. S., Ewers, B. E., ... & Cleary, M. B. (2008). Shrub encroachment in North American grasslands: shifts in growth form dominance rapidly alters control of ecosystem carbon inputs. Global Change Biology, 14(3), 615-623.	2008	North America	United States	Shrub/woodland cover gain		
Asner, G. P., Archer, S., hughes, r. F., Ansley, R. J., & Wessman, C. A. 2003. Net changes in regional woody vegetation cover and carbon storage in Texas Drylands, 1937–1999. Global Change Biology, 9(3), 316-335.	2003	North America	USA	Shrub/woodland cover gain	1937	1999
Barger, N. N., Archer, S. R., Campbell, J. L., Huang, C. Y., Morton, J. A., & Knapp, A. K. (2011). Woody plant proliferation in North American drylands: a synthesis of impacts on ecosystem carbon balance. Journal of Geophysical Research: Biogeosciences, 116(G4).	2011	North America	United States	Shrub/woodland cover gain	1960	1983
Archer, S., Boutton, T.W. and Hibbard, K.A. (2001). Trees in Grasslands: Biogeochemical Consequences of Woody Plant Expansion. Global Biogeochemical Cycles in the Climate System, 115-137.	2001	North America	USA	Shrub/woodland cover gain	1941	1983
Knapp, A. K., Briggs, J. M., Collins, S. L., Archer, S. R., BRET-HARTE, M. S., Ewers, B. E., ... & Cleary, M. B. (2008). Shrub encroachment in North American grasslands: shifts in growth form dominance rapidly alters control of ecosystem carbon inputs. Global Change Biology, 14(3), 615-623.	2008	North America	United States	Shrub/woodland cover gain		

Barger, N. N., Archer, S. R., Campbell, J. L., Huang, C. Y., Morton, J. A., & Knapp, A. K. (2011). Woody plant proliferation in North American drylands: a synthesis of impacts on ecosystem carbon balance. Journal of Geophysical Research: Biogeosciences, 116(G4).	2011	North America	United States	Shrub/woodland cover gain	1956	2000
Knight, C.L., Briggs, J.M. and Nellis, M.D., 1994. Expansion of gallery forest on Konza Prairie research natural area, Kansas, USA. Landscape Ecology. 9, 117-125.	1994	North America	United States	Forest cover gain	1939	1985
Bragg, T.B. and Hulbert, L.C., 1976. Woody plant invasion of unburned Kansas bluestem prairie. Journal of Range Management. 29, 19-24.	1976	North America	USA	Forest cover gain	1937	1969
Gehring, J.L., & Bragg, T.B. (1992). Changes in prairie vegetation under eastern red cedar (Juniperus virginiana L.) in an eastern Nebraska bluestem prairie. The American Midland Naturalist, 128(2), 209-217.	1992	North America	United States	Forest cover gain	1960	1982
Briggs, J.M., Hoch, G.A. and Johnson, L.C., 2002. Assessing the rate, mechanisms, and consequences of the conversion of tallgrass prairie to Juniperus virginiana forest. Ecosystems. 5, 578-586.	2002	North America	United States	Forest cover gain	1969	1978
Knapp, A. K., Briggs, J. M., Collins, S. L., Archer, S. R., BRET-HARTE, M. S., Ewers, B. E., ... & Cleary, M. B. (2008). Shrub encroachment in North American grasslands: shifts in growth form dominance rapidly alters control of ecosystem carbon inputs. Global Change Biology, 14(3), 615-623.	2008	North America	United States	Shrub/woodland cover gain		
Minnesota Department of Natural Resources. 2007. Federal conditions report 2007. 24 pp. http://fhm.fs.fed.us/fhh/fhh_07/mn_fhh_07.pdf	2007	North America	United States	Forest/woodland decline	2004	2007
Faber-Langendoen, D. and Tester, J.R., 1993. Oak mortality in sand savannas following drought in east-central Minnesota. Bulletin of the Torrey Botanical Club, pp.248-256.	1993	North America	Unites States	Forest/woodland decline	1987	1989
Barger, N. N., Archer, S. R., Campbell, J. L., Huang, C. Y., Morton, J. A., & Knapp, A. K. (2011). Woody plant proliferation in North American drylands: a synthesis of impacts on ecosystem carbon balance. Journal of Geophysical Research: Biogeosciences, 116(G4).	2011	North America	United States	Forest cover gain	1979	2002
Aguilar, A., 2003. Patterns of forest regeneration In Celaque National Park, Honduras. Online Journal of Space Communication, 3, p.31.	2003	North America	Honduras	Forest cover gain	1987	1998
Wijdeven, S.M. and Kuzee, M.E., 2000. Seed availability as a limiting factor in forest recovery processes in Costa Rica. Restoration ecology, 8(4), pp.414-424.	2000	North America	Costa Rico	Forest cover gain	1993	1995
Chazdon, R.L., Brenes, A.R. and Alvarado, B.V., 2005. Effects of climate and stand age on annual tree dynamics in tropical second-growth rain forests. Ecology, 86(7), pp.1808-1815.	2005	North America	Costa Rica	Forest cover gain	1997	2003

Turner, M.G., Pearson, S.M., Bolstad, P. and Wear, D.N., 2003. Effects of land-cover change on spatial pattern of forest communities in the Southern Appalachian Mountains (USA). Landscape Ecology, 18(5), pp.449-464.	2003	North America	United States	Forest cover gain	1950	1990
Mitchell, C.E., Turner, M.G. and Pearson, S.M., 2002. Effects of historical land use and forest patch size on myrmecochores and ant communities. Ecological applications, 12(5), pp.1364-1377.	2002	North America	United States	Forest cover gain	1900	2002
Copenheaver, C.A., Fuhrman, N.E., Stephens Gellerstedt, L., & Gellerstedt, P.A. (2004). Tree encroachment in forest openings: A case study from Buffalo Mountain, Virginia. Castanea, 69(4), 297-308.	2004	North America	United States	Shrub/woodland cover gain	1920	1990
Cavanaugh, K.C., Kellner,J.R., Forde, A.J., Gruner, D.S., Parker, J.D., Rodriguez, W., & Feller, I.C. (2013). Poleward expansion of mangroves is a threshold response to decreased frequency of extreme cold events. Proceedings of the National Academy of Science, 111(2), 723-727.	2013	North America	United States	Shrub/woodland cover gain	1984	2011
Condit, R., Hubbell, S.P. and Foster, R.B., 1995. Mortality rates of 205 neotropical tree and shrub species and the impact of a severe drought. Ecological monographs, 65(4), pp.419-439.	1995	North America	Panama	Forest/woodland decline	1982	1985
Atkins, J. W., Epstein, H. E., & Welsch, D. L. (2018). Using Landsat imagery to map understory shrub expansion relative to landscape position in a mid-Appalachian watershed. Ecosphere, 9(10). https://doi.org/10.1002/ecs2.2404	2018	North America	United States	Shrub/woodland cover gain	1986	2011
Lavoie, C., & Payette, S. (1994). Recent fluctuations of the lichen-spruce forest limit in subarctic Quebec. *Journal of Ecology*, 725-734.	1994	North America	Canada	Forest cover gain		
Angers-Blondin, S., and S. Boudreau. 2017. Expansion dynamics and performance of the dwarf shrub Empetrum hermaphroditum (Ericaceae) on a Subarctic sand dune system, Nunavik (Canada). Arctic, Antarctic, and Alpine Research 49:201–211.	2017	North America	Canada	Herbaceous cover gain	2007	2012
Lescop-Sinclair, Kateri, and Serge Payette. "Recent advance of the arctic treeline along the eastern coast of Hudson Bay." *Journal of Ecology* (1995): 929-936.	1995	North America	Canada	Forest cover gain		
Ropars P and Boudreau S 2012 Shrub expansion at the forest tundra ecotone: spatial heterogeneity linked to local topography Environ. Res. Lett. at press	2012	North America	Canada	Shrub/woodland cover gain	1957	2008
Ropars P and Boudreau S 2012 Shrub expansion at the forest tundra ecotone: spatial heterogeneity linked to local topography Environ. Res. Lett. at press	2012	North America	Canada	Shrub/woodland cover gain	1957	2008
Hill G B and Henry G H R 2011 Responses of High Arctic wet sedge tundra to climate warming since 1980 Glob. Change Biol. 17 276–87	2011	North America	Canada	Shrub/woodland cover gain	1981	2005

Knapp, A. K., Briggs, J. M., Collins, S. L., Archer, S. R., BRET-HARTE, M. S., Ewers, B. E., ... & Cleary, M. B. (2008). Shrub encroachment in North American grasslands: shifts in growth form dominance rapidly alters control of ecosystem carbon inputs. Global Change Biology, 14(3), 615-623.	2008	North America	United States	Shrub/woodland cover gain		
Boulanger-Lapointe, N., E. Lévesque, S. Boudreau, G. H. R. Henry, and N. M. Schmidt. 2014. Population structure and dynamics of Arctic willow (Salix arctica) in the High Arctic. Journal of Biogeography 41:1967–1978.	2014	North America	Canada	Herbaceous cover gain	1988	2009
Hudson, J., and G. Henry. 2009. Increased plant biomass in a High Arctic heath community from 1981 to 2008. Ecology 90:2657–2663.	2009	North America	Canada	Shrub/woodland cover gain	1995	2007
Huang, H., J. C. Zinnert, L. K. Wood, D. R. Young, and P. D'Odorico. 2018. Non-linear shift from grassland to shrubland in temperate barrier islands. *Ecology* 99:1671–1681.	2018	North America	United States	Shrub/woodland cover gain	1984	2016
Sittaro, F., Paquette, A., Messier, C., & Nock, C. A. (2017). Tree range expansion in eastern North America fails to keep pace with climate warming at northern range limits. *Global Change Biology*, *23*(8), 3292-3301.	2017	North America	Canada	Forest cover gain	1970	2012
Jones, A.R.C. and Hendershot, W.H., 1989. Maple decline in Quebec: a discussion of possible causes and the use of fertilizers to limit damage. The Forestry Chronicle, 65(4), pp.280-287.	1989	North America	Eastern North America	Forest/woodland decline	1980	1990
Brice, M. H., Cazelles, K., Legendre, P., & Fortin, M. J. (2019). Disturbances amplify tree community responses to climate change in the temperate–boreal ecotone. *Global Ecology and Biogeography*, *28*(11), 1668-1681.	2019	North America	Canada	Forest cover gain	1970	2016
Foster, D.R., Motzkin, G. and Slater, B., 1998. Land-use history as long-term broad-scale disturbance: regional forest dynamics in central New England. Ecosystems, 1(1), pp.96-119.	1998	North America	United States	Forest cover gain	1830	1985
Brice, M. H., Cazelles, K., Legendre, P., & Fortin, M. J. (2019). Disturbances amplify tree community responses to climate change in the temperate–boreal ecotone. *Global Ecology and Biogeography*, *28*(11), 1668-1681.	2019	North America	Canada	Forest cover gain	1970	2016
Parés-Ramos, I., Gould, W. and Aide, T., 2008. Agricultural abandonment, suburban growth, and forest expansion in Puerto Rico between 1991 and 2000. Ecology and Society, 13.	2008	North America	Puerto Rico	Forest cover gain	1991	2000
Tremblay, B., Lévesque, E. & Boudreau, S. (2012). Recent expansion of erect shrubs in the Low Arctic: Evidence from Eastern Nunavik. *Environ. Res. Lett.*, 7.	2012	North America	Canada	Shrub/woodland cover gain	1964	2003
Tremblay, B., Lévesque, E. & Boudreau, S. (2012). Recent expansion of erect shrubs in the Low Arctic: Evidence from Eastern Nunavik. *Environ. Res. Lett.*, 7.	2013	North America	Canada	Forest cover gain	1964	2003

Tremblay B 2010 Augmentation récente du couvert ligneux érigé dans les environs de Kangiqsualujjuaq (Nunavik, Québec) MSc thesis Université du Québec à Trois-Rivières, Trois-Rivières, Québec, Canada	2010	North America	Canada	Shrub/woodland cover gain	1964	2003
Chinea, J.D., 2002. Tropical forest succession on abandoned farms in the Humacao Municipality of eastern Puerto Rico. Forest Ecology and Management, 167(1-3), pp.195-207.	2002	North America	Puerto Rico	Forest cover gain	1936	1995
Payette, S., 2007. Contrasted dynamics of northern Labrador tree lines caused by climate change and migrational lag. Ecology. 88, 770-780.	2007	North America	Canada	Forest/woodland decline	~1700	present
Upshall M 2011 Simulating vegetation change in the Torngat Mountains, Labrador using a cellular automata-Markov chain model MSc thesis Memorial University of Newfoundland, St. John's, NF, Canada	2011	North America	Canada	Shrub/woodland cover gain	1985	2001
Payette, S., 2007. Contrasted dynamics of northern Labrador tree lines caused by climate change and migrational lag. Ecology. 88, 770-780.	2007	North America	Canada	Forest cover gain	1940	2007
Myers-Smith, I.H., Forbes, B.C., Wilmking, M., Hallinger, M., Lantz, T., Blok, D., Tape, K.D., Macias-Fauria, M., Sass-Klaassen, U., & Lévesque, E. (2011). Shrub expansion in tundra ecosystems: dynamics, impacts and research priorities. Environmental Research Letters, 6(4), 1-15.	2011	North America	Canada	Shrub/woodland cover gain		
Myers-Smith, I.H., Forbes, B.C., Wilmking, M., Hallinger, M., Lantz, T., Blok, D., Tape, K.D., Macias-Fauria, M., Sass-Klaassen, U., & Lévesque, E. (2011). Shrub expansion in tundra ecosystems: dynamics, impacts and research priorities. Environmental Research Letters, 6(4), 1-15.	2011	North America	Canada	Shrub/woodland cover gain		
Daniëls F J A, de Molenaar J G, Chytrý M and Tichý L 2011 Vegetation change in southeast Greenland? Tasiilaq revisited after 40 years Appl. Veg Sci. 14 230–41	2011	North America	Greenland	Shrub/woodland cover gain	1968	2007
Lantz T C, Kokelj S V, Gergel S E and Henry G H R 2009 Relative impacts of disturbance and temperature: persistent changes in microenvironment and vegetation in retrogressive thaw slumps Glob. Change Biol. 15 1664–75	2009	North America	Canada	Shrub/woodland cover gain		
Millar, C. I., Westfall, R. D., Delany, D. L., King, J. C., & Graumlich, L. J. (2004). Response of subalpine conifers in the Sierra Nevada, California, USA, to 20th-century warming and decadal climate variability. Arctic, Antarctic, and Alpine Research, 36(2), 181-200.	2004	North America	United States	Forest cover gain	1945	1976
McIntyre, P. J., Thorne, J. H., Dolanc, C. R., Flint, A. L., Flint, L. E., Kelly, M., & Ackerly, D. D. (2015). Twentieth-century shifts in forest structure in California: Denser forests, smaller trees, and increased dominance of oaks. Proceedings of the National Academy of Sciences, 112(5), 1458-1463.	2015	North America	United States	Forest cover gain	1930	2000

McIntyre, P. J., Thorne, J. H., Dolanc, C. R., Flint, A. L., Flint, L. E., Kelly, M., & Ackerly, D. D. (2015). Twentieth-century shifts in forest structure in California: Denser forests, smaller trees, and increased dominance of oaks. Proceedings of the National Academy of Sciences, 112(5), 1458-1463.	2015	North America	United States	Forest type change	1930	2000
Hollister, R. D., J. L. May, K. S. Kremers, C. E. Tweedie, S. F. Oberbauer, J. A. Liebig, T. F. Botting, R. T. Barrett, and J. L. Gregory. 2015. Warming experiments elucidate the drivers of observed directional changes in tundra vegetation. Ecology and Evolution 5:1881–1895.	2015	North America	United States	Shrub/woodl and cover gain	1994	2012
Benedict, J. B. (1984). Rates of tree-island migration, Colorado Rocky Mountains, USA. *Ecology*, *65*(3), 820-823.	1984	North America	United States	Forest cover gain		
Daly, C., & Shankman, D. (1985). Seedling establishment by conifers above tree limit on Niwot Ridge, Front Range, Colorado, USA. *Arctic and Alpine Research*, *17*(4), 389-400.	1985	North America	United States	Forest cover gain		
Weisberg, Peter J., and William L. Baker. "Spatial variation in tree seedling and krummholz growth in the forest-tundra ecotone of Rocky Mountain National Park, Colorado, USA." *Arctic and Alpine Research* 27, no. 2 (1995): 116-129.	1995	North America	United States			
Elliott, G. P., & Baker, W. L. (2004). Quaking aspen (Populus tremuloides Michx.) at treeline: a century of change in the San Juan Mountains, Colorado, USA. *Journal of Biogeography*, *31*(5), 733-745.	2004	North America	United States	Forest type change		
Coop, J. D., & Givnish, T. J. (2007). Spatial and temporal patterns of recent forest encroachment in montane grasslands of the Valles Caldera, New Mexico, USA. *Journal of Biogeography*, *34*(5), 914-927.	2007	North America	United States	Forest cover gain		
Andersen, M. D., & Baker, W. L. (2005). Reconstructing landscape-scale tree invasion using survey notes in the Medicine Bow Mountains, Wyoming, USA. *Landscape Ecology*, *21*(2), 243-258.	2005	North America	United States	Forest cover gain	1895	2005
Cocke, A. E., Fule, P. Z., & Crouse, J. E. (2005). Forest change on a steep mountain gradient after extended fire exclusion: San Francisco Peaks, Arizona, USA. *Journal of Applied Ecology*, *42*(5), 814-823.	2005	North America	United States	Forest cover gain	1876	2000
Moore, M. M., & Huffman, D. W. (2004). Tree encroachment on meadows of the north rim, Grand Canyon National Park, Arizona, USA. *Arctic, Antarctic, and Alpine Research*, *36*(4), 474-483.	2004	North America	United States	Forest cover gain	1930	2000
Klasner, F. L., & Fagre, D. B. (2002). A half century of change in alpine treeline patterns at Glacier National Park, Montana, USA. *Arctic, Antarctic, and Alpine Research*, *34*(1), 49-56.	2002	North America	United States	Forest cover gain	1945	1991
Butler, D. R., & DeChano, L. M. (2001). Environmental change in Glacier National Park, Montana: an assessment through repeat photography from fire lookouts. Physical Geography, 22(4), 291-304.	2001	North America	United States	Forest cover gain		

Alftine K.J., Malanson G.P. & Fagre D.B. (2003). Feedback-driven response to multidecadal climatic variability at an alpine treeline. *Physical Geography*, 24, 520-535.	2003	North America	United States	Forest cover gain	1940	1980
Baker, W., & Weisberg, P. (1997). Using GIS to model tree population parameters in the Rocky Mountain National Park forest–tundra ecotone. Journal of Biogeography, 24(4), 513-526.	1997	North America	United States	Forest cover gain		
Weisberg, P. J., Lingua, E., & Pillai, R. B. (2007). Spatial patterns of pinyon–juniper woodland expansion in central Nevada. *Rangeland Ecology & Management*, *60*(2), 115-124.	2007	North America	United States	Shrub/woodland cover gain		
Bunn, A. G., Waggoner, L. A., & Graumlich, L. J. (2005). Topographic mediation of growth in high elevation foxtail pine (Pinus balfouriana Grev. et Balf.) forests in the Sierra Nevada, USA. *Global Ecology and Biogeography*, *14*(2), 103-114.	2005	North America	United States	Forest cover gain		2001
Vale, T. R. (1987). Vegetation change and park purposes in the high elevations of Yosemite National Park, California. *Annals of the Association of American Geographers*, *77*(1), 1-18.	1987	North America	United States	Forest cover gain		
Brink, V.C. (1959). A directional change in the subapline forest-heath ecotone in Garibaldi Park, British Columbia. Ecology, 40(1), 10-16.	1959	North America	Canada	Forest cover gain	1918	1958
Danby, R. K., & Hik, D. S. (2007). Variability, contingency and rapid change in recent subarctic alpine tree line dynamics. *Journal of Ecology*, *95*(2), 352-363.	2007	North America	Canada	Forest cover gain	1947	1989
Epstein, H. E., Calef, M. P., Walker, M. D., Stuart Chapin III, F., & Starfield, A. M. (2004). Detecting changes in arctic tundra plant communities in response to warming over decadal time scales. *Global Change Biology*, *10*(8), 1325-1334.	2004	North America	United States	Shrub/woodland cover gain		
Suarez, F., Binkley, D., Kaye, M. W., & Stottlemyer, R. (1999). Expansion of forest stands into tundra in the Noatak National Preserve, northwest Alaska. *Ecoscience*, *6*(3), 465-470.	1999	North America	United States	Forest cover gain		
Beckage, B., Osborne, B., Gavin, D. G., Pucko, C., Siccama, T., & Perkins, T. (2008). A rapid upward shift of a forest ecotone during 40 years of warming in the Green Mountains of Vermont. Proceedings of the National Academy of Sciences, 105(11), 4197-4202.	2008	North America	United States	Forest type change	1962	2005
Gamache, I., & Payette, S. (2005). Latitudinal response of subarctic tree lines to recent climate change in eastern Canada. *Journal of Biogeography*, *32*(5), 849-862.	2005	North America	Canada	Forest cover gain		
Gamache, I., & Payette, S. (2004). Height growth response of tree line black spruce to recent climate warming across the forest-tundra of eastern Canada. *Journal of Ecology*, *92*(5), 835-845.	2004	North America	Canada	Forest cover gain		
Gamache, I., & Payette, S. (2005). Latitudinal response of subarctic tree lines to recent climate change in eastern Canada. *Journal of Biogeography*, *32*(5), 849-862.	2005	North America	Canada	Forest cover gain		

Gamache, I., & Payette, S. (2005). Latitudinal response of subarctic tree lines to recent climate change in eastern Canada. *Journal of Biogeography*, *32*(5), 849-862.	2005	North America	Canada	Forest cover gain		
Pereg, D., & Payette, S. (1998). Development of black spruce growth forms at treeline. *Plant Ecology*, *138*(2), 137-147.	1998	North America	Canada	Forest cover gain		~1998
Caccianiga, M., & Payette, S. (2006). Recent advance of white spruce (Picea glauca) in the coastal tundra of the eastern shore of Hudson Bay (Québec, Canada). *Journal of Biogeography*, *33*(12), 2120-2135.	2006	North America	Canada	Forest cover gain		
Caccianiga, M., & Payette, S. (2006). Recent advance of white spruce (Picea glauca) in the coastal tundra of the eastern shore of Hudson Bay (Québec, Canada). *Journal of Biogeography*, *33*(12), 2120-2135.	2006	North America	Canada	Forest cover gain		
Caccianiga, M., & Payette, S. (2006). Recent advance of white spruce (Picea glauca) in the coastal tundra of the eastern shore of Hudson Bay (Québec, Canada). *Journal of Biogeography*, *33*(12), 2120-2135.	2006	North America	Canada	Forest cover gain		
Caccianiga, M., & Payette, S. (2006). Recent advance of white spruce (Picea glauca) in the coastal tundra of the eastern shore of Hudson Bay (Québec, Canada). *Journal of Biogeography*, *33*(12), 2120-2135.	2006	North America	Canada	Forest cover gain		
Vallée, S., & Payette, S. (2004). Contrasted growth of black spruce (Picea mariana) forest trees at treeline associated with climate change over the last 400 years. *Arctic, Antarctic, and Alpine Research*, *36*(4), 400-406.	2004	North America	Canada	Forest cover gain	1800	2000
Körner, C., Sarris, D. and Christodoulakis, D., 2005. Long-term increase in climatic dryness in the East-Mediterranean as evidenced for the island of Samos. Regional Environmental Change, 5(1), pp.27-36.	2005	Europe	Greece	Forest/woodland decline	2000	2000
Cerrillo, R.N., Varo, M.A., Lanjeri, S. and Clemente, R.H., 2007. Cartografía de defoliación en los pinares de pino silvestre (Pinus sylvestris L.) y pino salgareño (Pinus nigra Arnold.) en la Sierra de los Filabres. Revista Ecosistemas, 16(3).	2007	Europe	Spain	Forest/woodland decline	2004	2006
Peñuelas, J., Lloret, F. and Montoya, R., 2001. Severe drought effects on Mediterranean woody flora in Spain. Forest Science, 47(2), pp.214-218.	2001	Europe	Spain	Forest/woodland decline	1994 & 1998	1994 & 1998
Markalas, S., 1992. Site and stand factors related to mortality rate in a fir forest after a combined incidence of drought and insect attack. Forest Ecology and Management, 47(1-4), pp.367-374.	1992	Europe	Greece	Forest/woodland decline	1987	1989
van Gils, H., Batsukh, O., Rossiter, D., Munthali, W. and Liberatoscioli, E., 2008. Forecasting the pattern and pace of Fagus forest expansion in Majella National Park, Italy. Applied Vegetation Science, 11(4), pp.539-546.	2008	Europe	Italy	Forest cover gain	1975	2003

Mancino, G., Nolè, A., Ripullone, F. and Ferrara, A., 2014. Landsat TM imagery and NDVI differencing to detect vegetation change: assessing natural forest expansion in Basilicata, southern Italy. iForest-Biogeosciences and Forestry, 7(2), p.75.	2014	Europe	Italy	Forest cover gain	1984	2010
Barbati, A., Corona, P., Salvati, L. and Gasparella, L., 2013. Natural forest expansion into suburban countryside: Gained ground for a green infrastructure?. Urban Forestry & Urban Greening. 12, 36-43.	2013	Europe	Italy	Shrub/woodl and cover gain	1974	2008
Acosta, A., Carranza, M.L. and Giancola, M., 2005. Landscape change and ecosystem classification in a municipal district of a small city (Isernia, Central Italy). Environmental Monitoring and Assessment, 108(1-3), pp.323-335.	2005	Europe	Italy	Forest cover gain	1954	1992
Cudlín, Pavel, Matija Klopčič, Roberto Tognetti, Frantisek Máli&, Concepción L. Alados, Peter Bebi, Karsten Grunewald et al. "Drivers of treeline shift in different European mountains." *Climate Research* 73, no. 1-2 (2017): 135-150.	2017	Europe	Bulgaria	Forest cover gain		
Peñuelas, J., Ogaya, R., Boada M., & Jump, A. S. 2007. Migration, invasion and decline: changes in recruitment andforest structure in a warming-linked shift of European beechforest in Catalonia (NE Spain). Ecography **30**, 829-837.	2007	Europe	Spain	Forest cover gain	1920	2003
Peñuelas, J., Ogaya, R., Boada M., & Jump, A. S. 2007. Migration, invasion and decline: changes in recruitment andforest structure in a warming-linked shift of European beechforest in Catalonia (NE Spain). Ecography **30**, 829-837.	2007	Europe	Spain	Forest cover gain	1910	2007
Peñuelas, J., Ogaya, R., Boada M., & Jump, A. S. 2007. Migration, invasion and decline: changes in recruitment andforest structure in a warming-linked shift of European beechforest in Catalonia (NE Spain). Ecography **30**, 829-837.	2007	Europe	Spain	Forest type change	1910	2007
Cudlín, Pavel, Matija Klopčič, Roberto Tognetti, Frantisek Máli&, Concepción L. Alados, Peter Bebi, Karsten Grunewald et al. "Drivers of treeline shift in different European mountains." *Climate Research* 73, no. 1-2 (2017): 135-150.	2017	Europe	macedonia	Forest cover gain	1934	2010
Cudlín, Pavel, Matija Klopčič, Roberto Tognetti, Frantisek Máli&, Concepción L. Alados, Peter Bebi, Karsten Grunewald et al. "Drivers of treeline shift in different European mountains." *Climate Research* 73, no. 1-2 (2017): 135-150.	2017	Europe	Italy	Forest cover gain	1954	2007
Ameztegui, A., Coll, L., Brotons, L., & Ninot, J. M. (2016). Land-use legacies rather than climate change are driving the recent upward shift of the mountain tree line in the Pyrenees. *Global Ecology and Biogeography*, *25*(3), 263-273.	2016	Europe	Spain	Forest cover gain	1956	2006

Feuillet, T., Birre, D., Milian, J., Godard, V., Clauzel, C., & Serrano-Notivoli, R. (2020). Spatial dynamics of alpine tree lines under global warming: What explains the mismatch between tree densification and elevational upward shifts at the tree line ecotone?. Journal of Biogeography, 47(5), 1056-1068.	2019	Europe	France	Forest cover gain	1953	2015
Feuillet, T., Birre, D., Milian, J., Godard, V., Clauzel, C., & Serrano-Notivoli, R. (2020). Spatial dynamics of alpine tree lines under global warming: What explains the mismatch between tree densification and elevational upward shifts at the tree line ecotone?. Journal of Biogeography, 47(5), 1056-1068.	2019	Europe	France	Forest cover gain	1953	2015
Feuillet, T., Birre, D., Milian, J., Godard, V., Clauzel, C., & Serrano-Notivoli, R. (2020). Spatial dynamics of alpine tree lines under global warming: What explains the mismatch between tree densification and elevational upward shifts at the tree line ecotone?. Journal of Biogeography, 47(5), 1056-1068.	2020	Europe	France	Forest cover gain	1953	2015
Feuillet, T., Birre, D., Milian, J., Godard, V., Clauzel, C., & Serrano-Notivoli, R. (2020). Spatial dynamics of alpine tree lines under global warming: What explains the mismatch between tree densification and elevational upward shifts at the tree line ecotone?. Journal of Biogeography, 47(5), 1056-1068.	2020	Europe	France	Forest cover gain	1953	2015
Cudlín, Pavel, Matija Klopčič, Roberto Tognetti, Frantisek Máli&, Concepción L. Alados, Peter Bebi, Karsten Grunewald et al. "Drivers of treeline shift in different European mountains." *Climate Research* 73, no. 1-2 (2017): 135-150.	2017	Europe	Spain	Forest cover gain	1956	2006
Cudlín, Pavel, Matija Klopčič, Roberto Tognetti, Frantisek Máli&, Concepción L. Alados, Peter Bebi, Karsten Grunewald et al. "Drivers of treeline shift in different European mountains." *Climate Research* 73, no. 1-2 (2017): 135-150.	2017	Europe	Bulgaria	Forest cover gain		
Mouillot, F., Ratte, J.P., Joffre, R., Mouillot, D. and Rambal, S., 2005. Long-term forest dynamic after land abandonment in a fire prone Mediterranean landscape (central Corsica, France). Landscape Ecology, 20(1), pp.101-112.	2005	Europe	France	Forest cover gain	1960	1990
Vennetier, M., Vila, B., Liang, E.Y., Guibal, F., Thabeet, A. and Gadbin-Henry, C., 2007. Impact of climate change on pine forest productivity and on the shift of a bioclimatic limit in a Mediterranean area. Options Méditerranéennes, Série A, 75, pp.189-197.	2007	Europe	France	Forest/woodland decline	2003	2008
Vennetier, M., Cecillon, L., Guénon, R., Schaffhauser, A., Vergnoux, A., Boichard, J.L., Bottéro, J.Y., Brun, J.J., Carrara, M., Cassagne, N. and Chandioux, O., 2008. Etude de l'impact d'incendies de forêt répétés sur la biodiversité et sur les sols: recherche d'indicateurs. Rapport final. Cemagref, Ministère de l'Agriculture et de la pêche, Union Européenne, Aix en Provence, 236.	2008	Europe	France	Forest/woodland decline	2006	2008

Preiss, E., Martin, J.L. and Debussche, M., 1997. Rural depopulation and recent landscape changes in a Mediterranean region: consequences to the breeding avifauna. Landscape ecology, 12(1), pp.51-61.	1997	Europe	France	Shrub/woodland cover gain	1978	1992
Argenti, G., Bianchetto, E., Ferretti, F., Giulietti, V., Milandri, M., Pelleri, F., Romagnoli, P., Signorini, M.A. and Venturi, E., 2006. Caratterizzazione di un'area pascoliva in fase di abbandono attualmente utilizzata in modo estensivo (S. Paolo in Alpe-S. Sofia, FC). Forest@-Journal of Silviculture and Forest Ecology, 3(3), p.387.	2006	Europe	Italy	Forest cover gain	1955	1997
Agnoletti, M., 2007. The degradation of traditional landscape in a mountain area of Tuscany during the 19th and 20th centuries: Implications for biodiversity and sustainable management. Forest ecology and Management, 249(1-2), pp.5-17.	2007	Europe	Italy	Forest cover gain	1832	2000
Vertui, F. and Tagliaferro, F., 1998. Scots pine (Pinus sylvestris L.) die-back by unknown causes in the Aosta Valley, Italy. Chemosphere, 36(4-5), pp.1061-1065.	1998	Europe	Italy	Forest/woodland decline	1985	1998
Laiolo, P., Dondero, F., Ciliento, E. and Rolando, A., 2004. Consequences of pastoral abandonment for the structure and diversity of the alpine avifauna. Journal of Applied Ecology, 41(2), pp.294-304.	2004	Europe	Italy	Forest cover gain	1954	2002
Gellrich, M., Baur, P., Robinson, B.H. and Bebi, P., 2008. Combining classification tree analyses with interviews to study why sub-alpine grasslands sometimes revert to forest: A case study from the Swiss Alps. Agricultural Systems, 96(1-3), pp.124-138.	2008	Europe	Switzerland	Forest cover gain	1950	2000
Cudlín, Pavel, Matija Klopčič, Roberto Tognetti, Frantisek Máli&, Concepción L. Alados, Peter Bebi, Karsten Grunewald et al. "Drivers of treeline shift in different European mountains." *Climate Research* 73, no. 1-2 (2017): 135-150.	2017	Europe	Slovenia	Forest cover gain		
Rigling, A., Bigler, C., Eilmann, B., Feldmeyer-Christe, E., Gimmi, U., Ginzler, C., ... & Wohlgemuth, T. (2013). Driving factors of a vegetation shift from Scots pine to pubescent oak in dry Alpine forests. *Global Change Biology*, *19*(1), 229-240.	2013	Europe	Switzerland	Forest type change	1983	2003
Rigling, A., Bigler, C., Eilmann, B., Feldmeyer-Christe, E., Gimmi, U., Ginzler, C., ... & Wohlgemuth, T. (2013). Driving factors of a vegetation shift from Scots pine to pubescent oak in dry Alpine forests. *Global Change Biology*, *19*(1), 229-240.	2013	Europe	Switzerland	Forest type change	1983	2003
Wermelinger, B., Rigling, A., Schneider Mathis, D. and Dobbertin, M., 2008. Assessing the role of bark-and wood-boring insects in the decline of Scots pine (Pinus sylvestris) in the Swiss Rhone valley. Ecological Entomology, 33(2), pp.239-249.	2008	Europe	Switzerland	Forest/woodland decline	2001	2005

Kienast, F., Flühler, H. and Schweingruber, F.H., 1981. Jahrringanalysen an Föhren (Pinus silvestris L.) aus immissionsgefährdeten Beständen des Mittelwallis (Saxon, Schweiz). Mitteilungen der Eidgenössischen Anstalt für das Forstliche Versuchswesen, 57, pp.415-32.	1981	Europe	Switzerland	Forest/woodland decline	1960	1978
Cudlín, Pavel, Matija Klopčič, Roberto Tognetti, Frantisek Máli&, Concepción L. Alados, Peter Bebi, Karsten Grunewald et al. "Drivers of treeline shift in different European mountains." *Climate Research* 73, no. 1-2 (2017): 135-150.	2017	Europe	Italy	Forest cover gain	1954	2018
Bolliger, J., Kienast, F., Soliva, R. and Rutherford, G., 2007. Spatial sensitivity of species habitat patterns to scenarios of land use change (Switzerland).` Landscape Ecology, 22(5), pp.773-789.	2007	Europe	Switzerland	Forest cover gain	1979	1997
Cudlín, Pavel, Matija Klopčič, Roberto Tognetti, Frantisek Máli&, Concepción L. Alados, Peter Bebi, Karsten Grunewald et al. "Drivers of treeline shift in different European mountains." *Climate Research* 73, no. 1-2 (2017): 135-150.	2017	Europe	Switzerland	Forest cover gain	1954	2018
Minerbi, S., 1993. Wie gesund sind unsere Walder? 10. Bericht uber den Zustand der Walder in Su dtirol. Agrar-und Forstbericht, Autonome Provinz Bozen. Assessorate fur Land-und Forstwirtschaft, p.40.	1993	Europe	Italy	Forest/woodland decline	1992	1992
Cannone, N., S. Sgorbati, and M. Guglielmin. 2007. Unexpected impacts of climate change on alpine vegetation. Frontiers in Ecology and the Environment 5:360–364.	2007	Europe	Switzerland	Shrub/woodland cover gain	1953	2003
Tasser, E. and Tappeiner, U., 2002. Impact of land use changes on mountain vegetation. Applied vegetation science, 5(2), pp.173-184.	2002	Europe	Italy	Forest cover gain	1932	1998
Tappeiner, U., Tasser, E., Leitinger, G., Cernusca, A. and Tappeiner, G., 2008. Effects of historical and likely future scenarios of land use on above-and belowground vegetation carbon stocks of an alpine valley. Ecosystems, 11(8), pp.1383-1400.	2008	Europe	Austria	Forest cover gain	1865	2003
Cech, T., Perny, L.B., 2000. Kiefernsterben in Tirol. Forstschutz-aktuell 22, 12–15.	2000	Europe	Austria	Forest/woodland decline	1991	1997
Kuemmerle, T., Kaplan, J.O., Prishchepov, A.V., Rylsky, I., Chaskovskyy, O., Tikunov, V.S. and Müller, D., 2015. Forest transitions in Eastern Europe and their effects on carbon budgets. Global change biology, 21(8), pp.3049-3061.	2015	Europe	Moldova	Forest cover gain	1915	2012
Petercord, R., 2008. Future endangerment of the European beech by bark and wood boring beetles in BadenWürttemberg. Mitteilungen der Deutsche Gesellschaft für Allgemeine und Angewandte Entomologie, 16, pp.247-250.	2008	Europe	Germany	Forest/woodland decline	2003	2006
Cudlín, Pavel, Matija Klopčič, Roberto Tognetti, Frantisek Máli&, Concepción L. Alados, Peter Bebi, Karsten Grunewald et al. "Drivers of treeline shift in different European mountains." *Climate Research* 73, no. 1-2 (2017): 135-150.	2017	Europe	Slovakia	Forest cover gain	1950	2018

Kuemmerle, T., Kaplan, J.O., Prishchepov, A.V., Rylsky, I., Chaskovskyy, O., Tikunov, V.S. and Müller, D., 2015. Forest transitions in Eastern Europe and their effects on carbon budgets. Global change biology, 21(8), pp.3049-3061.	2015	Europe	Ukraine	Forest cover gain	1917	2012
Treml, V., Wild, J., Chuman, T., & Potůčková, M. 2010. Assessing the change in cover of non-indigenous dwarf-pine using aerial photographs, a case study from the Hrubý Jeseník MTS., the Sudetes. Journal of Landscape Ecology, 3(2), 90-104.	2010	Europe	Czechia	Forest cover gain	1971/1973	2003
Treml, V., Wild, J., Chuman, T., & Potůčková, M. 2010. Assessing the change in cover of non-indigenous dwarf-pine using aerial photographs, a case study from the Hrubý Jeseník MTS., the Sudetes. Journal of Landscape Ecology, 3(2), 90-104.	2010	Europe	Czechia	Forest cover gain	1971/1973	2003
Cudlín, Pavel, Matija Klopčič, Roberto Tognetti, Frantisek Máli&, Concepción L. Alados, Peter Bebi, Karsten Grunewald et al. "Drivers of treeline shift in different European mountains." *Climate Research* 73, no. 1-2 (2017): 135-150.	2017	Europe	Czech republic	Forest cover gain	1936	2005
Treml, V., Wild, J., Chuman, T., & Potůčková, M. 2010. Assessing the change in cover of non-indigenous dwarf-pine using aerial photographs, a case study from the Hrubý Jeseník MTS., the Sudetes. Journal of Landscape Ecology, 3(2), 90-104.	2010	Europe	Czechia	Forest cover gain	1971/1973	2003
Treml, V., Wild, J., Chuman, T., & Potůčková, M. 2010. Assessing the change in cover of non-indigenous dwarf-pine using aerial photographs, a case study from the Hrubý Jeseník MTS., the Sudetes. Journal of Landscape Ecology, 3(2), 90-104.	2010	Europe	Czechia	Forest cover gain	1971/1973	2003
Treml, V., Wild, J., Chuman, T., & Potůčková, M. 2010. Assessing the change in cover of non-indigenous dwarf-pine using aerial photographs, a case study from the Hrubý Jeseník MTS., the Sudetes. Journal of Landscape Ecology, 3(2), 90-104.	2010	Europe	Czechia	Forest cover gain	1971/1973	2003
Treml, V., Wild, J., Chuman, T., & Potůčková, M. 2010. Assessing the change in cover of non-indigenous dwarf-pine using aerial photographs, a case study from the Hrubý Jeseník MTS., the Sudetes. Journal of Landscape Ecology, 3(2), 90-104.	2010	Europe	Czechia	Forest cover gain	1971/1973	2003
Treml, V., Wild, J., Chuman, T., & Potůčková, M. 2010. Assessing the change in cover of non-indigenous dwarf-pine using aerial photographs, a case study from the Hrubý Jeseník MTS., the Sudetes. Journal of Landscape Ecology, 3(2), 90-104.	2010	Europe	Czechia	Forest cover gain	1971/1973	2003
Kuemmerle, T., Kaplan, J.O., Prishchepov, A.V., Rylsky, I., Chaskovskyy, O., Tikunov, V.S. and Müller, D., 2015. Forest transitions in Eastern Europe and their effects on carbon budgets. Global change biology, 21(8), pp.3049-3061.	2015	Europe	Russia	Forest cover gain	1939	2012

Siwkcki, R. and Ufnalski, K., 1998. Review of oak stand decline with special reference to the role of drought in Poland. European Journal of Forest Pathology, 28(2), pp.99-112.	1998	Europe	Poland	Forest/woodland decline	1979	1987
Kuemmerle, T., Kaplan, J.O., Prishchepov, A.V., Rylsky, I., Chaskovskyy, O., Tikunov, V.S. and Müller, D., 2015. Forest transitions in Eastern Europe and their effects on carbon budgets. Global change biology, 21(8), pp.3049-3061.	2015	Europe	Belarus	Forest cover gain	1930	2012
Kuemmerle, T., Kaplan, J.O., Prishchepov, A.V., Rylsky, I., Chaskovskyy, O., Tikunov, V.S. and Müller, D., 2015. Forest transitions in Eastern Europe and their effects on carbon budgets. Global change biology, 21(8), pp.3049-3061.	2015	Europe	Russia	Forest cover gain	1917	2012
Kuemmerle, T., Kaplan, J.O., Prishchepov, A.V., Rylsky, I., Chaskovskyy, O., Tikunov, V.S. and Müller, D., 2015. Forest transitions in Eastern Europe and their effects on carbon budgets. Global change biology, 21(8), pp.3049-3061.	2015	Europe	Russia	Forest cover gain	1975	2012
Kuemmerle, T., Kaplan, J.O., Prishchepov, A.V., Rylsky, I., Chaskovskyy, O., Tikunov, V.S. and Müller, D., 2015. Forest transitions in Eastern Europe and their effects on carbon budgets. Global change biology, 21(8), pp.3049-3061.	2015	Europe	Lithuania	Forest cover gain	1922	2012
Kuemmerle, T., Kaplan, J.O., Prishchepov, A.V., Rylsky, I., Chaskovskyy, O., Tikunov, V.S. and Müller, D., 2015. Forest transitions in Eastern Europe and their effects on carbon budgets. Global change biology, 21(8), pp.3049-3061.	2015	Europe	Russia	Forest cover gain	1921	2012
Olsson, E.G.A., Austrheim, G. and Grenne, S.N., 2000. Landscape change patterns in mountains, land use and environmental diversity, Mid-Norway 1960–1993. Landscape ecology, 15(2), pp.155-170.	2001	Europe	Norway	Forest cover gain	1964	1989
Cudlín, Pavel, Matija Klopčič, Roberto Tognetti, Frantisek Máli&, Concepción L. Alados, Peter Bebi, Karsten Grunewald et al. "Drivers of treeline shift in different European mountains." *Climate Research* 73, no. 1-2 (2017): 135-150.	2017	Europe	Norway	Forest cover gain	1915	2007
Truong, C., Palmé, A. E., & Felber, F. (2007). Recent invasion of the mountain birch Betula pubescens ssp. tortuosa above the treeline due to climate change: genetic and ecological study in northern Sweden. *Journal of evolutionary biology*, *20*(1), 369-380.	2007	Europe	Sweden	Forest cover gain		
Vowles, T., Lovehav, C., Molau, U. & Björk, R.G. (2017). Contrasting impacts of reindeer grazing in two tundra grasslands. *Environ. Res. Lett.*, 12.	2017	Europe	Sweden	Shrub/woodland cover gain	1995	2012
Olsson, E.G.A., Austrheim, G. and Grenne, S.N., 2000. Landscape change patterns in mountains, land use and environmental diversity, Mid-Norway 1960–1993. Landscape ecology, 15(2), pp.155-170.	2000	Europe	Norway	Forest cover gain	1963	1993
Kjallgren & Kullman 1998	1998	Europe	Sweden	Forest cover gain		

Frost, G. V., and H. E. Epstein. 2014. Tall shrub and tree expansion in Siberian tundra ecotones since the 1960s. Global Change Biology 20:1264–1277.	2014	Europe	Russia	Shrub/woodland cover gain	1969	2009
Tsvetkov, V.F., Tsvetkov, V.I., 2007. The problem of spruce forests—mortality in the Arkhangelsk Region. In: Dying Spruce Forests of Arkhangelsk Region. Problems and Means of their Solution, Department of Forest Complex of Arkhangelsk Region, Arkhangelsk, Russian Federation, pp. 20–30.	2007	Europe	Russia	Forest/woodland decline	2004	2006
Frost, G. V., and H. E. Epstein. 2014. Tall shrub and tree expansion in Siberian tundra ecotones since the 1960s. Global Change Biology 20:1264–1277.	2014	Europe	Russia	Shrub/woodland cover gain	1969	2010
Frost, G. V., H. E. Epstein, D. A. Walker, G. Matyshak, and K. Ermokhina. 2013. Patterned-ground facilitates shrub expansion in Low Arctic tundra. Environmental Research Letters 8:015035.	2013	Europe	Russia	Shrub/woodland cover gain	1968	2010
Frost, G. V., and H. E. Epstein. 2014. Tall shrub and tree expansion in Siberian tundra ecotones since the 1960s. Global Change Biology 20:1264–1277.	2014	Europe	Russia	Shrub/woodland cover gain	1968	2003
Frost, G. V., and H. E. Epstein. 2014. Tall shrub and tree expansion in Siberian tundra ecotones since the 1960s. Global Change Biology 20:1264–1277.	2014	Europe	Russia	Shrub/woodland cover gain	1968	2004
Frost, G. V., H. E. Epstein, D. A. Walker, G. Matyshak, and K. Ermokhina. 2013. Patterned-ground facilitates shrub expansion in Low Arctic tundra. Environmental Research Letters 8:015035.	2013	Europe	Russia	Shrub/woodland cover gain	1968	2010
Frost, G. V., and H. E. Epstein. 2014. Tall shrub and tree expansion in Siberian tundra ecotones since the 1960s. Global Change Biology 20:1264–1277.	2014	Europe	Russia	Shrub/woodland cover gain	1968	2010
Frost, G. V., and H. E. Epstein. 2014. Tall shrub and tree expansion in Siberian tundra ecotones since the 1960s. Global Change Biology 20:1264–1277.	2014	Europe	Russia	Shrub/woodland cover gain	1968	2011
Vowles, T., Lovehav, C., Molau, U. & Björk, R.G. (2017). Contrasting impacts of reindeer grazing in two tundra grasslands. *Environ. Res. Lett.*, 12.	2017	Europe	Sweden	Shrub/woodland cover gain	1995	2012
Cudlín, Pavel, Matija Klopčič, Roberto Tognetti, Frantisek Máli&, Concepción L. Alados, Peter Bebi, Karsten Grunewald et al. "Drivers of treeline shift in different European mountains." *Climate Research* 73, no. 1-2 (2017): 135-150.	2017	Europe	Northern Scandes	Forest cover gain	1958	2008
Molau, U. 2010. Long-term impacts of observed and induced climate change on tussock tundra near its southern limit in northern Sweden. Plant Ecology and Diversity 3:29–34.	2010	Europe	Sweden	Shrub/woodland cover gain	1995	2006
Rundqvist, S., Hedenås, H., Sandström, A., Emanuelsson, U., Eriksson, H., Jonasson, C., *et al.* (2011). Tree and shrub expansion over the past 34 years at the tree-line near Abisko, Sweden. *Ambio*, 40, 683–692.	2011	Europe	Sweden	Shrub/woodland cover gain	1976	2010

Rundqvist, S., Hedenås, H., Sandström, A., Emanuelsson, U., Eriksson, H., Jonasson, C., *et al.* (2011). Tree and shrub expansion over the past 34 years at the tree-line near Abisko, Sweden. *Ambio*, 40, 683–692.	2011	Europe	Sweden	Forest cover gain	1976	2010
Frost, G. V., and H. E. Epstein. 2014. Tall shrub and tree expansion in Siberian tundra ecotones since the 1960s. Global Change Biology 20:1264–1277.	2014	Europe	Russia	Shrub/woodland cover gain	1965	2010
Frost, G. V., and H. E. Epstein. 2014. Tall shrub and tree expansion in Siberian tundra ecotones since the 1960s. Global Change Biology 20:1264–1277.	2014	Europe	Russia	Forest cover gain	1965	2010
Frost, G. V., and H. E. Epstein. 2014. Tall shrub and tree expansion in Siberian tundra ecotones since the 1960s. Global Change Biology 20:1264–1277.	2014	Europe	Russia	Shrub/woodland cover gain	1966	2010
Frost, G. V., and H. E. Epstein. 2014. Tall shrub and tree expansion in Siberian tundra ecotones since the 1960s. Global Change Biology 20:1264–1277.	2014	Europe	Russia	Forest cover gain	1966	2010
Kapfer, J., and K. Popova. 2020. Changes in subarctic vegetation after one century of land use and climate change. Journal of Vegetation Science 00:1–12.	2020	Europe	Russia	Shrub/woodland cover gain	1930	2016
Kapfer, J., and K. Popova. 2020. Changes in subarctic vegetation after one century of land use and climate change. Journal of Vegetation Science 00:1–12.	2020	Europe	Russia	Herbaceous cover gain	1930	2016
Kapfer, J., and K. Popova. 2020. Changes in subarctic vegetation after one century of land use and climate change. Journal of Vegetation Science 00:1–12.	2020	Europe	Russia	Grass cover loss	1930	2016
Frost, G. V., and H. E. Epstein. 2014. Tall shrub and tree expansion in Siberian tundra ecotones since the 1960s. Global Change Biology 20:1264–1277.	2014	Europe	Russia	Shrub/woodland cover gain	1966	2009
Frost, G. V., and H. E. Epstein. 2014. Tall shrub and tree expansion in Siberian tundra ecotones since the 1960s. Global Change Biology 20:1264–1277.	2014	Europe	Russia	Forest cover gain	1966	2009
Frost, G. V., and H. E. Epstein. 2014. Tall shrub and tree expansion in Siberian tundra ecotones since the 1960s. Global Change Biology 20:1264–1277.	2014	Europe	Russia	Shrub/woodland cover gain	1966	2009
Frost, G. V., and H. E. Epstein. 2014. Tall shrub and tree expansion in Siberian tundra ecotones since the 1960s. Global Change Biology 20:1264–1277.	2014	Europe	Russia	Forest cover gain	1966	2009
Frost, G. V., and H. E. Epstein. 2014. Tall shrub and tree expansion in Siberian tundra ecotones since the 1960s. Global Change Biology 20:1264–1277.	2014	Europe	Russia	Shrub/woodland cover gain	1965	2009
Schmidt, N. M., Kristensen, D. K., Michelsen, A. & Bay, C. 2012. High Arctic plant community responses to a decade of ambient warming. Biodiversity, 12, 191-199.	2012	Europe	Greenland	Grass cover loss	1997	2008
Hofgaard, A., Kullman, L., & Alexandersson, H. (1991). Response of old-growth montane Picea abies (L.) Karst. forest to climatic variability in northern Sweden. New Phytologist, 119(4), 585-594.	1991	Europe	Sweden	Forest cover gain	1938	1988

Julio Camarero, J., & Gutiérrez, E. (2007). Response of Pinus uncinata recruitment to climate warming and changes in grazing pressure in an isolated population of the Iberian system (NE Spain). *Arctic, Antarctic, and Alpine Research*, *39*(2), 210-217.	2007	Europe	Spain	Forest cover gain		
Camarero, J. J., & Gutiérrez, E. (2004). Pace and pattern of recent treeline dynamics: response of ecotones to climatic variability in the Spanish Pyrenees. *Climatic change*, *63*(1-2), 181-200.	2004	Europe	Spain	Forest cover gain	1900	1997
Camarero, J. J., & Gutiérrez, E. (2004). Pace and pattern of recent treeline dynamics: response of ecotones to climatic variability in the Spanish Pyrenees. *Climatic change*, *63*(1-2), 181-200.	2004	Europe	Spain	Forest cover gain	1900	1997
Motta, R., & Nola, P. (2001). Growth trends and dynamics in sub-alpine forest stands in the Varaita Valley (Piedmont, Italy) and their relationships with human activities and global change. *Journal of Vegetation Science*, *12*(2), 219-230.	2001	Europe	Italy	Forest cover gain		
Motta, R., & Nola, P. (2001). Growth trends and dynamics in sub-alpine forest stands in the Varaita Valley (Piedmont, Italy) and their relationships with human activities and global change. *Journal of Vegetation Science*, *12*(2), 219-230.	2001	Europe	Italy	Forest cover gain		
Didier, L. (2001). Invasion patterns of European larch and Swiss stone pine in subalpine pastures in the French Alps. *Forest Ecology and Management*, *145*(1-2), 67-77.	2001	Europe	Switzerland	Forest type change	1950	2000
Vittoz, P., Rulence, B., Largey, T., & Freléchoux, F. (2008). Effects of climate and land-use change on the establishment and growth of cembran pine (Pinus cembra L.) over the altitudinal treeline ecotone in the Central Swiss Alps. Arctic, Antarctic, and Alpine Research, 40(1), 225-232.	2008	Europe	Switzerland	Forest cover gain		
Vittoz, P., Rulence, B., Largey, T., & Freléchoux, F. (2008). Effects of climate and land-use change on the establishment and growth of cembran pine (Pinus cembra L.) over the altitudinal treeline ecotone in the Central Swiss Alps. Arctic, Antarctic, and Alpine Research, 40(1), 225-232.	2008	Europe	Switzerland	Forest cover gain		
Gehrig-Fasel, J., Guisan, A., & Zimmermann, N. E. (2007). Tree line shifts in the Swiss Alps: climate change or land abandonment?. *Journal of vegetation science*, *18*(4), 571-582.	2007	Europe	Switzerland	Forest cover gain	1985	1997
Gehrig-Fasel, J., Guisan, A., & Zimmermann, N. E. (2007). Tree line shifts in the Swiss Alps: climate change or land abandonment?. *Journal of vegetation science*, *18*(4), 571-582.	2007	Europe	Switzerland	Forest cover gain	1985	1997
Vittoz, P., Rulence, B., Largey, T., & Freléchoux, F. (2008). Effects of climate and land-use change on the establishment and growth of cembran pine (Pinus cembra L.) over the altitudinal treeline ecotone in the Central Swiss Alps. Arctic, Antarctic, and Alpine Research, 40(1), 225-232.	2008	Europe	Switzerland	Forest cover gain		

Motta, R., Nola, P., & Piussi, P. (2002). Long-term investigations in a strict forest reserve in the eastern Italian Alps: spatio-temporal origin and development in two multi-layered subalpine stands. *Journal of Ecology*, *90*(3), 495-507.	2002	Europe	Italy	Forest cover gain	1920	2000
Motta, R., Nola, P., & Piussi, P. (2002). Long-term investigations in a strict forest reserve in the eastern Italian Alps: spatio-temporal origin and development in two multi-layered subalpine stands. *Journal of Ecology*, *90*(3), 495-507.	2002	Europe	Italy	Forest cover gain		2000
Kern, Z., & Popa, I. (2008). Changes of frost damage and treeline advance for swiss Stone Pine in the Calimani Mts.(Eastern Carpathians, Romania). *Acta Silvatica et Lignaria Hungarica*, *4*, 39-48.	2008	Europe	Romania	Forest cover gain	1910	2006
Dullinger, S., Dirnböck, T., & Grabherr, G. (2003). Patterns of shrub invasion into high mountain grasslands of the Northern Calcareous Alps, Austria. *Arctic, Antarctic, and Alpine Research*, *35*(4), 434-441.	2003	Europe	Austria	Forest cover gain		
LinLinderholm, H. W. (2002). Twentieth-century Scots pine growth variations in the central Scandinavian Mountains related to climate change. Arctic, Antarctic, and Alpine Research, 34(4), 440-449.derholm 2002	2002	Europe	Sweden	Forest cover gain	1931	1960
Grace, J., & Norton, D. A. (1990). Climate and growth of Pinus sylvestris at its upper altitudinal limit in Scotland: evidence from tree growth-rings. *The Journal of Ecology*, 601-610.	1990	Europe	United Kingdom	Forest cover gain		
Dalen, L., & Hofgaard, A. (2005). Differential regional treeline dynamics in the Scandes Mountains. *Arctic, Antarctic, and Alpine Research*, *37*(3), 284-296.	2005	Europe	Norway	Forest cover gain		
Dalen, L., & Hofgaard, A. (2005). Differential regional treeline dynamics in the Scandes Mountains. *Arctic, Antarctic, and Alpine Research*, *37*(3), 284-296.	2005	Europe	Norway	Forest cover gain		
Dalen, L., & Hofgaard, A. (2005). Differential regional treeline dynamics in the Scandes Mountains. *Arctic, Antarctic, and Alpine Research*, *37*(3), 284-296.	2005	Europe	Norway	Forest cover gain		
Dalen, L., & Hofgaard, A. (2005). Differential regional treeline dynamics in the Scandes Mountains. *Arctic, Antarctic, and Alpine Research*, *37*(3), 284-296.	2005	Europe	Norway	Forest cover gain		
Kullman, L. (2003). Recent reversal of Neoglacial climate cooling trend in the Swedish Scandes as evidenced by mountain birch tree-limit rise. Global and planetary change, 36(1-2), 77-88.n 2003	2003	Europe	Sweden	Forest cover gain		
Kullman, L. (1983). Past and present tree-lines of different species in the Handolan valley, central Sweden. In *Tree-Line Ecology: Proceedings of the Northern Quebec Tree-Line Conference. Centre d'etudes nordiques, Universite Laval, Quebec, 1983*.	1983	Europe	Sweden	Forest cover gain		
Kullman, L. (2002). Rapid recent range-margin rise of tree and shrub species in the Swedish Scandes. *Journal of ecology*, *90*(1), 68-77.	2002	Europe	Sweden	Forest cover gain	1950	2000

Kullman, L. (2005, January). Pine (Pinus sylvestris) treeline dynamics during the past millennium—a population study in west-central Sweden. In *Annales Botanici Fennici* (pp. 95-106). Finnish Zoological and Botanical Publishing Board.	2005	Europe	Sweden	Forest cover gain	1950	2000
Kullman, L. (1996). Rise and demise of cold-climate Picea abies forest in Sweden. *New Phytologist*, *134*(2), 243-256.	1996	Europe	Sweden	Shrub/woodl and cover gain		
Kullman, L. (1993). Pine (Pinus sylvestris L.) tree-limit surveillance during recent decades, Central Sweden. *Arctic and Alpine Research*, *25*(1), 24-31.	1993	Europe	Sweden	Forest cover gain		
Hofgaard, A. (1997). Inter-relationships between treeline position, species diversity, land use and climate change in the central Scandes Mountains of Norway. *Global Ecology and Biogeography Letters*, 419-429.	1997	Europe	Norway	Forest cover gain		
Juntunen, V., Neuvonen, S., Norokorpi, Y., & Tasanen, T. (2002). Potential for timberline advance in northern Finland, as revealed by monitoring during 1983-99. *Arctic*, 348-361.	2002	Europe	Finland	Forest cover gain	1983	1999
Juntunen, V., Neuvonen, S., Norokorpi, Y., & Tasanen, T. (2002). Potential for timberline advance in northern Finland, as revealed by monitoring during 1983-99. *Arctic*, 348-361.	2002	Europe	Finland	Forest cover gain	1983	1999
Juntunen, V., Neuvonen, S., Norokorpi, Y., & Tasanen, T. (2002). Potential for timberline advance in northern Finland, as revealed by monitoring during 1983-99. *Arctic*, 348-361.	2002	Europe	Finland	Forest cover gain	1983	1999
Autio, J. (2006). Environmental factors controlling the position of the actual timberline and treeline on the fells of Finnish Lapland. *Acta Universitatis Ouluensis A Scientiae Rerum Naturalium*, *452*.	2006	Europe	Finland	Forest cover gain		
Juntunen, V., Neuvonen, S., Norokorpi, Y., & Tasanen, T. (2002). Potential for timberline advance in northern Finland, as revealed by monitoring during 1983-99. *Arctic*, 348-361.	2002	Europe	Finland	Forest cover gain	1983	1999
Juntunen, V., Neuvonen, S., Norokorpi, Y., & Tasanen, T. (2002). Potential for timberline advance in northern Finland, as revealed by monitoring during 1983-99. *Arctic*, 348-361.	2002	Europe	Finland	Forest cover gain	1983	1999
Wilson S D and Nilsson C 2009 Arctic alpine vegetation change over 20 years Glob. Change Biol. 15 1676–84	2009	Europe	Sweden	Shrub/woodl and cover gain		
Juntunen, V., Neuvonen, S., Norokorpi, Y., & Tasanen, T. (2002). Potential for timberline advance in northern Finland, as revealed by monitoring during 1983-99. *Arctic*, 348-361.	2002	Europe	Finland	Forest cover gain	1983	1999
Dalen, L., & Hofgaard, A. (2005). Differential regional treeline dynamics in the Scandes Mountains. *Arctic, Antarctic, and Alpine Research*, *37*(3), 284-296.	2005	Europe	Sweden	Forest cover gain		
Dalen, L., & Hofgaard, A. (2005). Differential regional treeline dynamics in the Scandes Mountains. *Arctic, Antarctic, and Alpine Research*, *37*(3), 284-296.	2005	Europe	Sweden	Forest cover gain		

Dalen, L., & Hofgaard, A. (2005). Differential regional treeline dynamics in the Scandes Mountains. *Arctic, Antarctic, and Alpine Research*, *37*(3), 284-296.	2005	Europe	Sweden	Forest cover gain		
Dalen, L., & Hofgaard, A. (2005). Differential regional treeline dynamics in the Scandes Mountains. *Arctic, Antarctic, and Alpine Research*, *37*(3), 284-296.	2005	Europe	Sweden	Forest cover gain		
Hallinger M and Wilmking M 2011 No change without a cause—why climate change remains the most plausible reason for shrub growth dynamics in Scandinavia New Phytol. 189 902–8	2011	Europe	Sweden	Shrub/woodland cover gain		
Myers-Smith, I.H., Forbes, B.C., Wilmking, M., Hallinger, M., Lantz, T., Blok, D., Tape, K.D., Macias-Fauria, M., Sass-Klaassen, U., & Lévesque, E. (2011). Shrub expansion in tundra ecosystems: dynamics, impacts and research priorities. Environmental Research Letters, 6(4), 1-15.	2011	Europe	Sweden	Shrub/woodland cover gain		
Myers-Smith, I.H., Forbes, B.C., Wilmking, M., Hallinger, M., Lantz, T., Blok, D., Tape, K.D., Macias-Fauria, M., Sass-Klaassen, U., & Lévesque, E. (2011). Shrub expansion in tundra ecosystems: dynamics, impacts and research priorities. Environmental Research Letters, 6(4), 1-15.	2011	Europe	Sweden	Shrub/woodland cover gain		
Juntunen, V., Neuvonen, S., Norokorpi, Y., & Tasanen, T. (2002). Potential for timberline advance in northern Finland, as revealed by monitoring during 1983-99. *Arctic*, 348-361.	2002	Europe	Finland	Forest cover gain	1983	1999
Juntunen, V., Neuvonen, S., Norokorpi, Y., & Tasanen, T. (2002). Potential for timberline advance in northern Finland, as revealed by monitoring during 1983-99. *Arctic*, 348-361.	2002	Europe	Finland	Forest cover gain	1983	1999
Juntunen, V., Neuvonen, S., Norokorpi, Y., & Tasanen, T. (2002). Potential for timberline advance in northern Finland, as revealed by monitoring during 1983-99. *Arctic*, 348-361.	2002	Europe	Finland	Forest cover gain	1983	1999
Juntunen, V., Neuvonen, S., Norokorpi, Y., & Tasanen, T. (2002). Potential for timberline advance in northern Finland, as revealed by monitoring during 1983-99. *Arctic*, 348-361.	2002	Europe	Finland	Forest cover gain	1983	1999
Juntunen, V., Neuvonen, S., Norokorpi, Y., & Tasanen, T. (2002). Potential for timberline advance in northern Finland, as revealed by monitoring during 1983-99. *Arctic*, 348-361.	2002	Europe	Finland	Forest cover gain	1983	1999
Dalen, L., & Hofgaard, A. (2005). Differential regional treeline dynamics in the Scandes Mountains. *Arctic, Antarctic, and Alpine Research*, *37*(3), 284-296.	2005	Europe	Norway	Forest cover gain		
Dalen, L., & Hofgaard, A. (2005). Differential regional treeline dynamics in the Scandes Mountains. *Arctic, Antarctic, and Alpine Research*, *37*(3), 284-296.	2005	Europe	Norway	Forest cover gain		
Dalen, L., & Hofgaard, A. (2005). Differential regional treeline dynamics in the Scandes Mountains. *Arctic, Antarctic, and Alpine Research*, *37*(3), 284-296.	2005	Europe	Norway	Forest cover gain		

Dalen, L., & Hofgaard, A. (2005). Differential regional treeline dynamics in the Scandes Mountains. *Arctic, Antarctic, and Alpine Research*, *37*(3), 284-296.	2005	Europe	Norway	Forest cover gain		
Juntunen, V., Neuvonen, S., Norokorpi, Y., & Tasanen, T. (2002). Potential for timberline advance in northern Finland, as revealed by monitoring during 1983-99. *Arctic*, 348-361.	2002	Europe	Finland	Forest cover gain	1983	1999
Juntunen, V., Neuvonen, S., Norokorpi, Y., & Tasanen, T. (2002). Potential for timberline advance in northern Finland, as revealed by monitoring during 1983-99. *Arctic*, 348-361.	2002	Europe	Finland	Forest cover gain	1983	1999
Juntunen, V., Neuvonen, S., Norokorpi, Y., & Tasanen, T. (2002). Potential for timberline advance in northern Finland, as revealed by monitoring during 1983-99. *Arctic*, 348-361.	2002	Europe	Finland	Forest cover gain	1983	1999
Juntunen, V., Neuvonen, S., Norokorpi, Y., & Tasanen, T. (2002). Potential for timberline advance in northern Finland, as revealed by monitoring during 1983-99. *Arctic*, 348-361.	2002	Europe	Finland	Forest cover gain	1983	1999
Ravolainen V T, Bråthen K A, Ims R A, Yoccoz N G, Henden J-A and Killengreen S T 2011 Rapid, landscape scale responses in riparian tundra vegetation to exclusion of small and large mammalian herbivores Basic Appl. Ecol. 12 643–53	2011	Europe	Norway	Shrub/woodland cover gain	2006	2008
Myers-Smith, I.H., Forbes, B.C., Wilmking, M., Hallinger, M., Lantz, T., Blok, D., Tape, K.D., Macias-Fauria, M., Sass-Klaassen, U., & Lévesque, E. (2011). Shrub expansion in tundra ecosystems: dynamics, impacts and research priorities. Environmental Research Letters, 6(4), 1-15.	2011	Europe	Sweden	Shrub/woodland cover gain		
Myers-Smith, I.H., Forbes, B.C., Wilmking, M., Hallinger, M., Lantz, T., Blok, D., Tape, K.D., Macias-Fauria, M., Sass-Klaassen, U., & Lévesque, E. (2011). Shrub expansion in tundra ecosystems: dynamics, impacts and research priorities. Environmental Research Letters, 6(4), 1-15.	2011	Europe	Sweden	Shrub/woodland cover gain		
Cuevas, J. G. (2002). Episodic regeneration at the Nothofagus pumilio alpine timberline in Tierra del Fuego, Chile. *Journal of Ecology*, *90*(1), 52-60.	2002	South America	Chile	Forest cover gain	1920	1980
Passos, F. B., Marimon, B. S., Phillips, O. L., Morandi, P. S., das Neves, E. C., Elias, F., ... & Junior, B. H. M. (2018). Savanna turning into forest: concerted vegetation change at the ecotone between the Amazon and "Cerrado" biomes. Brazilian Journal of Botany, 41(3), 611-619.	2018	South America	Brazil	Shrub/woodland cover gain	2008	2015
Passos, F. B., Marimon, B. S., Phillips, O. L., Morandi, P. S., das Neves, E. C., Elias, F., ... & Junior, B. H. M. (2018). Savanna turning into forest: concerted vegetation change at the ecotone between the Amazon and "Cerrado" biomes. Brazilian Journal of Botany, 41(3), 611-619.	2018	South America	Brazil	Shrub/woodland cover gain	2008	2015

Srur, A. M., Villalba, R., Rodríguez-Catón, M., Amoroso, M. M., & Marcotti, E. (2018). Climate and Nothofagus pumilio establishment at upper treelines in the Patagonian Andes. *Frontiers in Earth Science*, *6*, 57.	2015	South America	Argentina	Forest cover gain		
DURIGAN, G. . Observation on the southern cerrados and their relationships with the core area. In: T. Pennington; P. Lewis Gwilym; F. A. Ratter. (Org.). Neotropical Savannas and Dry Forests: Diversity, Biogeography and Conservation. London: Taylor & Francis, 2006, v. , p. 67-77.	2006	South America	Brazil	Shrub/woodland cover gain	1962	2003
DURIGAN, G. ; SARAIVA, I. R. ; GURGEL-GARRIDO, L. M. A. ; GARRIDO, M. A. O. ; PECHE FILHO, A. . Fitossociologia e evolução da densidade da vegetacao do cerrado, Assis-SP.. Boletim Técnico If, São Paulo, v. 41, p. 59-78, 1987	1987	South America	Brazil	Shrub/woodland cover gain	1962	1984
PINHEIRO, E.S ; DURIGAN, G.2009 . Spatial and temporal dynamics (1962-2006) of Cerrado vegetation types in a protected area, southeastern Brazil. Revista Brasileira de Botânica 32:441-454, 2009.	2009	South America	Brazil	Shrub/woodland cover gain	1962	2006
Unpublished data	TBC	South America	Brazil	Shrub/woodland cover gain	2006	2011
Unpublished data	TBC	South America	Brazil	Shrub/woodland cover gain	2005	2012
Unpublished data	TBC	South America	Brazil	Shrub/woodland cover gain	2005	2012
Pinheiro, M.H.O. 2006. Composição e estrutura de uma comunidade savânica em gradiente topográfico no município de Corumbataí (SP, Brasil). Tese de Doutorado. Universidade Estadual Paulista Júlio de Mesquista Filho - UNESP (Biologia Vegetal). 117 p.	2006	South America	Brazil	Shrub/woodland cover gain	1962	2005
Cardoso, E.; Moreno, M.I.C.; Bruna, E.M.; Vasconcelos, H.F. 2009. CHANGES IN CERRADO VEGETATION PHYSIOGNOMIES: 18 YEARS OF ECOLOGICAL SUCCESSION AT ESTAÇÃO ECOLÓGICA DO PANGA, UBERLÂNDIA - MG. Caminhos da Geografia, 10(32):254-268	2009	South America	Brazil	Forest cover gain	1987	2005
Rosan, T. M., Aragão, L. E., Oliveras, I., Phillips, O. L., Malhi, Y., Gloor, E., & Wagner, F. H. (2019). Extensive 21st-century woody encroachment in South America's savanna. *Geophysical Research Letters*, *46*(12), 6594-6603.	2019	South America	Brazil	Shrub/woodland cover gain	2001	2015
Aide, T. M., Grau, H. R., Graesser, J., Andrade-Nuñez, M. J., Aráoz, E., Barros, A. P., ... & Peralvo, M. (2019). Woody vegetation dynamics in the tropical and subtropical Andes from 2001 to 2014: Satellite image interpretation and expert validation. Global change biology, 25(6), 2112-2126.	2019	South America	Bolivia	Forest cover gain	2001	2014

Rezende, A.V. 2002. Diversidade, estrutura, dinâmica e prognose do crescimento de um cerrado sensu stricto submetido a diferentes distúrbios por desmatamento. Curitiba, 2002. Tese (Doutorado em Engenharia Florestal). Universidade Federal do Paraná.	2002	South America	Brazil	Shrub/woodland cover gain	1995	2000
Eugênio, C.U.O. 2011. Dinâmica temporal do estrato herbáceo-arbustivo em comunidades campestres no Brasil Central. 110f. Tese (Mestrado em Engenharia Florestal), Universidade de Brasília, Brasília - DF	2011	South America	Brazil	Shrub/woodland cover gain	2000	2009
Almeida, R.F. 2013. O cerrado sensu stricto da Fazenda Água Limpa, Brasília, DF:mudanças florísticas em 27 anos de monitoramento. Brasília, 2013. 46 p.Dissertação (Mestrado em Botânica). Universidade de Brasília	2013	South America	Faz Água Limpa, DF	Shrub/woodland cover gain	1985	2012
Souza, A.J.B. 2010. Estrutura e dinâmica da vegetação lenhosa de cerrado sensu stricto no período de 19 anos, na reserva ecológica do IBGE, Distrito Federal, Brasil. 66 f. Tese (Mestrado em Ecologia), Universidade de Brasília, Brasília – DF.	2010	South America	Brazil	Shrub/woodland cover gain	1991	2009
Mews,H.A.; Marimon, B.S.; Maracahipes,L. 2011. Dinâmica da comunidade lenhosa de um Cerrado Típico na região Nordeste do Estado de Mato Grosso, Brasil. Biota Neotrop., 11(1): 73-82.	2011	South America	Brazil	Shrub/woodland cover gain	2002	2006
Lima, E.S.; Lima, H.S.; Ratter, J.A. 2009. Mudanças pós-fogo na estrutura e composição da vegetação lenhosa.em um cerrado mesotrófico, no período de cinco anos (1997-2002) em Nova Xavantina – MT. Cerne, Lavras, 15(4): 468-480	2009	South America	Brazil	Shrub/woodland cover gain	1997	2002
Roitman, I.; Felfili, J.M. Felfili; Rezende, A.V. 2008. Tree Dynamics of a Fire-Protected Cerrado Sensu Stricto Surrounded by Forest Plantations,over a 13-year Period (1991-2004) in Bahia, Brazil. Plant Ecology, 197 (2): 255-267.	2008	South America	Brazil	Shrub/woodland cover gain	1991	2004
Rosan, T. M., Aragão, L. E., Oliveras, I., Phillips, O. L., Malhi, Y., Gloor, E., & Wagner, F. H. (2019). Extensive 21st-century woody encroachment in South America's savanna. *Geophysical Research Letters*, *46*(12), 6594-6603.	2019	South America	Brazil	Forest cover gain	2001	2015
Rosan, T. M., Aragão, L. E., Oliveras, I., Phillips, O. L., Malhi, Y., Gloor, E., & Wagner, F. H. (2019). Extensive 21st-century woody encroachment in South America's savanna. *Geophysical Research Letters*, *46*(12), 6594-6603.	2019	South America	Brazil	Grass cover loss	2001	2015
Aide, T. M., Grau, H. R., Graesser, J., Andrade-Nuñez, M. J., Aráoz, E., Barros, A. P., ... & Peralvo, M. (2019). Woody vegetation dynamics in the tropical and subtropical Andes from 2001 to 2014: Satellite image interpretation and expert validation. Global change biology, 25(6), 2112-2126.	2019	South America	Peru	Forest cover gain	2001	2014
Aquino, F.G. ; Walter, B.M.T.; Ribeiro, J.F. 2007. Dinâmica de populações de espécies lenhosas de cerrado, Revista Árvore, Viçosa-MG, 31(5):793-803	2007	South America	Brazil	Shrub/woodland cover gain	1995	2002

Aquino, F.G. ; Walter, B.M.T.; Ribeiro, J.F. 2007. Dinâmica de populações de espécies lenhosas de cerrado, Revista Árvore, Viçosa-MG, 31(5):793-804	2007	South America	Brazil	Shrub/woodland cover gain	1995	2002
Rosan, T. M., Aragão, L. E., Oliveras, I., Phillips, O. L., Malhi, Y., Gloor, E., & Wagner, F. H. (2019). Extensive 21st-century woody encroachment in South America's savanna. *Geophysical Research Letters*, *46*(12), 6594-6603.	2019	South America	Brazil	Shrub/woodland cover gain	2001	2015
Günter, S., Weber, M., Erreis, R. and Aguirre, N., 2007. Influence of distance to forest edges on natural regeneration of abandoned pastures: a case study in the tropical mountain rain forest of Southern Ecuador. European Journal of Forest Research, 126(1), pp.67-75.	2007	South America	Eucador	Forest cover gain	1964	2002
Aide, T. M., Grau, H. R., Graesser, J., Andrade-Nuñez, M. J., Aráoz, E., Barros, A. P., ... & Peralvo, M. (2019). Woody vegetation dynamics in the tropical and subtropical Andes from 2001 to 2014: Satellite image interpretation and expert validation. Global change biology, 25(6), 2112-2126.	2019	South America	Ecuador	Forest cover gain	2001	2014
Moret, P., Muriel, P., Jaramillo, R., & Dangles, O. (2019). Humboldt's Tableau Physique revisited. *Proceedings of the National Academy of Sciences*, *116*(26), 12889-12894.	2019	South America	Ecuador	Shrub/woodland cover gain	1802	2017
Aide, T. M., Grau, H. R., Graesser, J., Andrade-Nuñez, M. J., Aráoz, E., Barros, A. P., ... & Peralvo, M. (2019). Woody vegetation dynamics in the tropical and subtropical Andes from 2001 to 2014: Satellite image interpretation and expert validation. Global change biology, 25(6), 2112-2126.	2019	South America	Colombia	Forest cover gain	2001	2014
Silva, L.C., Haridasan, M., Sternberg, L.S., Franco, A.C. and Hoffmann, W.A., 2010. Not all forests are expanding over central Brazilian savannas. Plant and Soil. 333, 431-442.	2010	South America	Brazil	Shrub/woodland cover gain		
Silva, L.C., Sternberg, L., Haridasan, M., Hoffmann, W.A., MIRALLES-WILHELM, F.E.R.N.A.N.D.O. and Franco, A.C., 2008. Expansion of gallery forests into central Brazilian savannas. Global Change Biology. 14, 2108-2118.	2008	South America	Brazil	Shrub/woodland cover gain	at least 3000-4000 yrs ago	
Lara, A., Villalba, R., Wolodarsky-Franke, A., Aravena, J. C., Luckman, B. H., & Cuq, E. (2005). Spatial and temporal variation in Nothofagus pumilio growth at tree line along its latitudinal range (35 40′–55 S) in the Chilean Andes. Journal of Biogeography, 32(5), 879-893.	2005	South America	Chile	Shrub/woodland cover gain	1829	1996
Lara, A., Villalba, R., Wolodarsky-Franke, A., Aravena, J. C., Luckman, B. H., & Cuq, E. (2005). Spatial and temporal variation in Nothofagus pumilio growth at tree line along its latitudinal range (35 40′–55 S) in the Chilean Andes. Journal of Biogeography, 32(5), 879-893.	2005	South America	Chile	Forest cover gain	1762	1996

Lara, A., Villalba, R., Wolodarsky-Franke, A., Aravena, J. C., Luckman, B. H., & Cuq, E. (2005). Spatial and temporal variation in Nothofagus pumilio growth at tree line along its latitudinal range (35 40′–55 S) in the Chilean Andes. Journal of Biogeography, 32(5), 879-893.	2005	South America	Chile	Forest cover gain	1768	1996
Lara, A., Villalba, R., Wolodarsky-Franke, A., Aravena, J. C., Luckman, B. H., & Cuq, E. (2005). Spatial and temporal variation in Nothofagus pumilio growth at tree line along its latitudinal range (35 40′–55 S) in the Chilean Andes. Journal of Biogeography, 32(5), 879-893.	2005	South America	Chile	Forest cover gain	1752	1996
Lara, A., Villalba, R., Wolodarsky-Franke, A., Aravena, J. C., Luckman, B. H., & Cuq, E. (2005). Spatial and temporal variation in Nothofagus pumilio growth at tree line along its latitudinal range (35 40′–55 S) in the Chilean Andes. Journal of Biogeography, 32(5), 879-893.	2005	South America	Chile	Forest cover gain	1763	1996
Cuevas, J. G. (2000). Tree recruitment at the Nothofagus pumilio alpine timberline in Tierra del Fuego, Chile. *Journal of Ecology*, *88*(5), 840-855.	2000	South America	Chile	Forest cover gain		
Cierjacks, A., Wesche, K., & Hensen, I. (2007). Potential lateral expansion of Polylepis forest fragments in central Ecuador. *Forest Ecology and Management*, *242*(2-3), 477-486.	2007	South America	Ecudor	Forest cover gain		
Bader, M. Y., van Geloof, I., & Rietkerk, M. (2007). High solar radiation hinders tree regeneration above the alpine treeline in northern Ecuador. *Plant Ecology*, *191*(1), 33-45.	2007	South America	Ecuador	Forest cover gain		
Daniels, L. D., & Veblen, T. T. (2003). Regional and local effects of disturbance and climate on altitudinal treelines in northern Patagonia. *Journal of Vegetation Science*, *14*(5), 733-742.	2003	South America	Patagonia	Forest cover gain		
Daniels, L. D., & Veblen, T. T. (2003). Regional and local effects of disturbance and climate on altitudinal treelines in northern Patagonia. *Journal of Vegetation Science*, *14*(5), 733-742.	2003	South America	Patagonia	Forest cover gain		
Cuevas, J. G. (2000). Tree recruitment at the Nothofagus pumilio alpine timberline in Tierra del Fuego, Chile. *Journal of Ecology*, *88*(5), 840-855.	2000	South America	Chile	Forest cover gain		
Cuevas, J. G. (2002). Episodic regeneration at the Nothofagus pumilio alpine timberline in Tierra del Fuego, Chile. *Journal of Ecology*, *90*(1), 52-60.	2002	South America	Chile	Forest cover gain	1800	1850
Byers, A. C. (2000). Contemporary landscape change in the Huascarán National Park and buffer zone, Cordillera Blanca, Peru. *Mountain Research and Development*, *20*(1), 52-63.	2000	South America	Peru	Forest cover gain	1936	1998
Cerrillo, R.N., Varo, M.A., Lanjeri, S. and Clemente, R.H., 2007. Cartografía de defoliación en los pinares de pino silvestre (Pinus sylvestris L.) y pino salgareño (Pinus nigra Arnold.) en la Sierra de los Filabres. Revista Ecosistemas, 16(3).	2007	Europe	Spain	Forest/woodland decline	2004	2006

French Forest Health Department (Département Santé des Forêts), 1998–1999, 2003–2008 Annual Reports	2008	Europe	France	Forest/woodland decline	2003	2008
Kienast, F., Flühler, H. and Schweingruber, F.H., 1981. Jahrringanalysen an Föhren (Pinus silvestris L.) aus immissionsgefährdeten Beständen des Mittelwallis (Saxon, Schweiz). Mitteilungen der Eidgenössischen Anstalt für das Forstliche Versuchswesen, 57, pp.415-32.	1981	Europe	Switzerland	Forest/woodland decline	1960	1978
Körner, C., Sarris, D. and Christodoulakis, D., 2005. Long-term increase in climatic dryness in the East-Mediterranean as evidenced for the island of Samos. Regional Environmental Change, 5(1), pp.27-36.	2005	Europe	Greece	Forest/woodland decline	2000	2000
Kuemmerle, T., Kaplan, J.O., Prishchepov, A.V., Rylsky, I., Chaskovskyy, O., Tikunov, V.S. and Müller, D., 2015. Forest transitions in Eastern Europe and their effects on carbon budgets. Global change biology, 21(8), pp.3049-3061.	2015	Europe	Former Soviet Union	Forest/woodland decline	1700	2000
Kuemmerle, T., Kaplan, J.O., Prishchepov, A.V., Rylsky, I., Chaskovskyy, O., Tikunov, V.S. and Müller, D., 2015. Forest transitions in Eastern Europe and their effects on carbon budgets. Global change biology, 21(8), pp.3049-3061.	2015	Europe	Belarus	Forest/woodland decline	1700	1930
Kuemmerle, T., Kaplan, J.O., Prishchepov, A.V., Rylsky, I., Chaskovskyy, O., Tikunov, V.S. and Müller, D., 2015. Forest transitions in Eastern Europe and their effects on carbon budgets. Global change biology, 21(8), pp.3049-3061.	2015	Europe	Lithuania	Forest/woodland decline	1700	1922
Kuemmerle, T., Kaplan, J.O., Prishchepov, A.V., Rylsky, I., Chaskovskyy, O., Tikunov, V.S. and Müller, D., 2015. Forest transitions in Eastern Europe and their effects on carbon budgets. Global change biology, 21(8), pp.3049-3061.	2015	Europe	Russia	Forest/woodland decline	1700	1921
Kuemmerle, T., Kaplan, J.O., Prishchepov, A.V., Rylsky, I., Chaskovskyy, O., Tikunov, V.S. and Müller, D., 2015. Forest transitions in Eastern Europe and their effects on carbon budgets. Global change biology, 21(8), pp.3049-3061.	2015	Europe	Russia	Forest/woodland decline	1700	1917
Kuemmerle, T., Kaplan, J.O., Prishchepov, A.V., Rylsky, I., Chaskovskyy, O., Tikunov, V.S. and Müller, D., 2015. Forest transitions in Eastern Europe and their effects on carbon budgets. Global change biology, 21(8), pp.3049-3061.	2015	Europe	Ukraine	Forest/woodland decline	1700	1917
Kuemmerle, T., Kaplan, J.O., Prishchepov, A.V., Rylsky, I., Chaskovskyy, O., Tikunov, V.S. and Müller, D., 2015. Forest transitions in Eastern Europe and their effects on carbon budgets. Global change biology, 21(8), pp.3049-3061.	2015	Europe	Moldova	Forest/woodland decline	1700	1915
Kuemmerle, T., Kaplan, J.O., Prishchepov, A.V., Rylsky, I., Chaskovskyy, O., Tikunov, V.S. and Müller, D., 2015. Forest transitions in Eastern Europe and their effects on carbon budgets. Global change biology, 21(8), pp.3049-3061.	2015	Europe	Russia	Forest/woodland decline	1700	1975

Kuemmerle, T., Kaplan, J.O., Prishchepov, A.V., Rylsky, I., Chaskovskyy, O., Tikunov, V.S. and Müller, D., 2015. Forest transitions in Eastern Europe and their effects on carbon budgets. Global change biology, 21(8), pp.3049-3061.	2015	Europe	Russia	Forest/woodl and decline	1700	2012
Kuemmerle, T., Kaplan, J.O., Prishchepov, A.V., Rylsky, I., Chaskovskyy, O., Tikunov, V.S. and Müller, D., 2015. Forest transitions in Eastern Europe and their effects on carbon budgets. Global change biology, 21(8), pp.3049-3061.	2015	Europe	Russia	Forest/woodl and decline	1700	1939
LinLinderholm, H. W. (2002). Twentieth-century Scots pine growth variations in the central Scandinavian Mountains related to climate change. Arctic, Antarctic, and Alpine Research, 34(4), 440-449.derholm 2002	2002	Europe	Sweden	Forest/woodl and decline	1901	1930
LinLinderholm, H. W. (2002). Twentieth-century Scots pine growth variations in the central Scandinavian Mountains related to climate change. Arctic, Antarctic, and Alpine Research, 34(4), 440-449.derholm 2002	2002	Europe	Sweden	Forest/woodl and decline	1961	1990
Markalas, S., 1992. Site and stand factors related to mortality rate in a fir forest after a combined incidence of drought and insect attack. Forest Ecology and Management, 47(1-4), pp.367-374.	1992	Europe	Greece	Forest/woodl and decline	1987	1989
Minerbi, S., 1993. Wie gesund sind unsere Walder? 10. Bericht uber den Zustand der Walder in Su dtirol. Agrar-und Forstbericht, Autonome Provinz Bozen. Assessorate fur Land-und Forstwirtschaft, p.40.	1993	Europe	Italy	Forest/woodl and decline	1992	1992
Peñuelas, J., Lloret, F. and Montoya, R., 2001. Severe drought effects on Mediterranean woody flora in Spain. Forest Science, 47(2), pp.214-218.	2001	Europe	Spain	Forest/woodl and decline	1994 & 1998	1994 & 1998
Petercord, R., 2008. Future endangerment of the European beech by bark and wood boring beetles in BadenWürttemberg. Mitteilungen der Deutsche Gesellschaft für Allgemeine und Angewandte Entomologie, 16, pp.247-250.	2008	Europe	Germany	Forest/woodl and decline	2003	2006
Schilli, S., Dobbertin, M., Rigling, A., Bucher, H.U. 2008. Waldfohrensterben um chur und im Wallis. Bundner Wald, 70-74.	2008	Europe	Switzerland	Forest/woodl and decline	2002	2007
Siwkcki, R. and Ufnalski, K., 1998. Review of oak stand decline with special reference to the role of drought in Poland. European Journal of Forest Pathology, 28(2), pp.99-112.	1998	Europe	Poland	Forest/woodl and decline	1979	1987
Solberg, S., 2004. Summer drought: a driver for crown condition and mortality of Norway spruce in Norway. Forest Pathology, 34(2), pp.93-104.	2004	Europe	Norway	Forest/woodl and decline	1988	2001
Tsopelas, P., Angelopoulos, A., Economou, A. and Soulioti, N., 2004. Mistletoe (Viscum album) in the fir forest of Mount Parnis, Greece. Forest ecology and management, 202(1-3), pp.59-65.	2004	Europe	Greece	Forest/woodl and decline	2000	2002

Tsvetkov, V.F., Tsvetkov, V.I., 2007. The problem of spruce forests—mortality in the Arkhangelsk Region. In: Dying Spruce Forests of Arkhangelsk Region. Problems and Means of their Solution, Department of Forest Complex of Arkhangelsk Region, Arkhangelsk, Russian Federation, pp. 20–30.	2007	Europe	Russia	Forest/woodl and decline	2004	2006
Vennetier, M., Cecillon, L., Guénon, R., Schaffhauser, A., Vergnoux, A., Boichard, J.L., Bottéro, J.Y., Brun, J.J., Carrara, M., Cassagne, N. and Chandioux, O., 2008. Etude de l'impact d'incendies de forêt répétés sur la biodiversité et sur les sols: recherche d'indicateurs. Rapport final. Cemagref, Ministère de l'Agriculture et de la pêche, Union Européenne, Aix en Provence, 236.	2008	Europe	France	Forest/woodl and decline	2006	2008
Vennetier, M., Vila, B., Liang, E.Y., Guibal, F., Thabeet, A. and Gadbin-Henry, C., 2007. Impact of climate change on pine forest productivity and on the shift of a bioclimatic limit in a Mediterranean area. Options Méditerranéennes, Série A, 75, pp.189-197.	2007	Europe	France	Forest/woodl and decline	2003	2008
Vertui, F. and Tagliaferro, F., 1998. Scots pine (Pinus sylvestris L.) die-back by unknown causes in the Aosta Valley, Italy. Chemosphere, 36(4-5), pp.1061-1065.	1998	Europe	Italy	Forest/woodl and decline	1985	1998
Wermelinger, B., Rigling, A., Schneider Mathis, D. and Dobbertin, M., 2008. Assessing the role of bark-and wood-boring insects in the decline of Scots pine (Pinus sylvestris) in the Swiss Rhone valley. Ecological Entomology, 33(2), pp.239-249.	2008	Europe	Switzerland	Forest/woodl and decline	2001	2005
Cech, T., Perny, L.B., 2000. Kiefernsterben in Tirol. Forstschutz-aktuell 22, 12–15.	2000	Europe	Austria	Forest/woodl and decline	1991	1997
Ermolenko, A., 2008, August. Climate change and mass-scale forest dieback: regional, national and international aspects. In Oral presentation at: International Conference ''Adaptation of Forests and Forest Management to Changing Climate with.	2008	Asia	Russia	Forest/woodl and decline	2005	2008
Fisher, M. and Gardner, A.S., 1995. The status and ecology of a Juniperus excelsa subsp. polycarpos woodland in the northern mountains of Oman. Vegetatio, 119(1), pp.33-51.	1995	Asia	Saudi Arabia and Oman	Forest/woodl and decline	~1990	~1995
Khan, J.A., Rodgers, W.A., Johnsingh, A.J.T. and Mathur, P.K., 1994. Tree and shrub mortality and debarking by sambar Cervus unicolor (Kerr) in Gir after a drought in Gujarat, India. Biological Conservation, 68(2), pp.149-154.	2001	Asia	India	Forest/woodl and decline	1987	1987
Kinnaird, M.F. and O'Brien, T.G., 1998. Ecological effects of wildfire on lowland rainforest in Sumatra. Conservation Biology, 12(5), pp.954-956.	1998	Asia	Indonesia	Forest/woodl and decline	1997	1998

Lim, J.H., Chun, J.H., Woo, S.Y. and Kim, Y.K., 2008, August. Increased declines of Korean fir forest caused by climate change in Mountain Halla, Korea. In Oral Presentation At: International Conference ''Adaptation of Forests and Forest Management to Changing Climate with Emphasis on Forest Health: A Review of Science, Policies, and Practices'', Umea, Sweden, FAO/IUFRO (pp. 25-28).	2008	Asia	South Korea	Forest/woodl and decline	2003	2008
Nakagawa, M., Tanaka, K., Nakashizuka, T., Ohkubo, T., Kato, T., Maeda, T., Sato, K., Miguchi, H., Nagamasu, H., Ogino, K. and Teo, S., 2000. Impact of severe drought associated with the 1997–1998 El Nino in a tropical forest in Sarawak. Journal of Tropical Ecology, 16(3), pp.355-367.	2000	Asia	Malaysia	Forest/woodl and decline	1997	1998
Nishimua, T.B., Suzuki, E., Kohyama, T. and Tsuyuzaki, S., 2007. Mortality and growth of trees in peat-swamp and heath forests in Central Kalimantan after severe drought. Plant Ecology, 188(2), pp.165-177.	2007	Asia	Indonesia	Forest/woodl and decline	1997	1998
Pandit, M.K., Manish, K. and Koh, L.P., 2014. Dancing on the roof of the world: ecological transformation of the Himalayan landscape. BioScience, 64(11), pp.980-992.	2014	Asia	Afganistan, Pakistan, India, Nepal, Bhutan, China, TAR, Northern Myanmar	Forest/woodl and decline	1960	1990
Semerci, A., Sanlı, B.N., Sahin, O., Celik, O., Balkız, G.B., Ceylan, S. and Argun, N., 2008, August. Examination of tree mortalities in semi-arid central Anatolian region of Turkey during last six-year period (2002–2007). In Book of Abstracts of the International Conference ''Adaptation of Forests and Forest Management to Changing Climate with Emphasis on Forest Health: A Review of Science, Policies, and Practices'', Umea, Sweden, FAO/IUFRO (p. 262).	2008	Asia	Turkey	Forest/woodl and decline	2002	2007
Van Nieuwstadt, M.G. and Sheil, D., 2005. Drought, fire and tree survival in a Borneo rain forest, East Kalimantan, Indonesia. Journal of Ecology, 93(1), pp.191-201.	2005	Asia	Indonesia & Malaysia	Forest/woodl and decline	1997	1998
Wang, H.B., Zhang, Z., Kong, X.B., Lui, S.C., Shen, Z.R., 2007. Preliminary deduction of potential distribution and alternative hosts of invasive pest, Dendroctonus valens (Coleoptera: Scolytidae). Scientia Silvae Sinicae 143, 71–76.	2007	Asia	China	Forest/woodl and decline	1998	2001
Werner, W.L., 1988. Canopy dieback in the upper montane rain forests of Sri Lanka. GeoJournal, 17(2), pp.245-248.	1988	Asia	Sri Lanka	Forest/woodl and decline	176	1980
Woods, P., 1989. Effects of logging, drought, and fire on structure and composition of tropical forests in Sabah, Malaysia. Biotropica, pp.290-298.	1989	Asia	Malaysia	Forest/woodl and decline	1982	1983

Giampietro, R. 2005. Modificações na estrutura e composição florística de matas ciliares na região do Médio Paranapanema (1992-2004). 118 f. Dissertação (Mestrado em Ciências da Engenharia Ambiental), Universidade de São Paulo, São Carlos, SP.	2005	South America	Brazil	Forest/woodland decline	1992	2004
Giampietro, R. 2005. Modificações na estrutura e composição florística de matas ciliares na região do Médio Paranapanema (1992-2004). 118 f. Dissertação (Mestrado em Ciências da Engenharia Ambiental), Universidade de São Paulo, São Carlos, SP.	2005	South America	Brazil	Forest/woodland decline	1992	2004
Kok, K., Verweij, P. A., & Beukema, H. (1995). Effects of cutting and grazing on Andean treeline vegetation. *Biodiversity and Conservation of Neotropical Montane Forest. Biodiversity and Conservation of Neotropical Montane Forests,* 527-539.	1995	South America	Colombia	Forest/woodland decline		
Phillips, O.L., Aragão, L.E., Lewis, S.L., Fisher, J.B., Lloyd, J., López-González, G., Malhi, Y., Monteagudo, A., Peacock, J., Quesada, C.A. and Van Der Heijden, G., 2009. Drought sensitivity of the Amazon rainforest. Science, 323(5919), pp.1344-1347.	2009	South America	Amazon Basin	Forest/woodland decline	2005	2005
Rolim, S.G., Jesus, R.M., Nascimento, H.E., Do Couto, H.T. and Chambers, J.Q., 2005. Biomass change in an Atlantic tropical moist forest: the ENSO effect in permanent sample plots over a 22-year period. Oecologia, 142(2), pp.238-246.	2005	South America	Brazil	Forest/woodland decline	1986, 1997	1989, 1999
Silva, L.C., Haridasan, M., Sternberg, L.S., Franco, A.C. and Hoffmann, W.A., 2010. Not all forests are expanding over central Brazilian savannas. Plant and Soil. 333, 431-442.	2010	South America	Brazil	Forest/woodland decline		
Suarez, M.L., Ghermandi, L. and Kitzberger, T., 2004. Factors predisposing episodic drought-induced tree mortality in Nothofagus–site, climatic sensitivity and growth trends. Journal of Ecology, 92(6), pp.954-966.	2004	South America	Argentina	Forest/woodland decline	1998	1999
Williamson, G.B., Laurance, W.F., Oliveira, A.A., Delamônica, P., Gascon, C., Lovejoy, T.E. and Pohl, L., 2000. Amazonian tree mortality during the 1997 El Nino drought. Conservation Biology, 14(5), pp.1538-1542.	2000	South America	Brazil	Forest/woodland decline	1997	1997
Aide, T. M., Grau, H. R., Graesser, J., Andrade-Nuñez, M. J., Aráoz, E., Barros, A. P., ... & Peralvo, M. (2019). Woody vegetation dynamics in the tropical and subtropical Andes from 2001 to 2014: Satellite image interpretation and expert validation. Global change biology, 25(6), 2112-2126.	2019	South America	Venezuela	Forest/woodland decline	2001	2014
Aide, T. M., Grau, H. R., Graesser, J., Andrade-Nuñez, M. J., Aráoz, E., Barros, A. P., ... & Peralvo, M. (2019). Woody vegetation dynamics in the tropical and subtropical Andes from 2001 to 2014: Satellite image interpretation and expert validation. Global change biology, 25(6), 2112-2126.	2019	South America	Argentina	Forest/woodland decline	2001	2014

Banfai, Daniel S., and David MJS Bowman. "Forty years of lowland monsoon rainforest expansion in Kakadu National Park, Northern Australia." Biological Conservation 131.4 (2006): 553-565.	2006	Australasia	Australia	Forest/woodland decline	1964	2004
Banfai, Daniel S., and David MJS Bowman. "Forty years of lowland monsoon rainforest expansion in Kakadu National Park, Northern Australia." Biological Conservation 131.4 (2006): 553-565.	2006	Australasia	Australia	Forest/woodland decline	1964	2004
Banfai, Daniel S., and David MJS Bowman. "Forty years of lowland monsoon rainforest expansion in Kakadu National Park, Northern Australia." Biological Conservation 131.4 (2006): 553-565.	2006	Australasia	Australia	Forest/woodland decline	1964	2004
Banfai, Daniel S., and David MJS Bowman. "Forty years of lowland monsoon rainforest expansion in Kakadu National Park, Northern Australia." Biological Conservation 131.4 (2006): 553-565.	2006	Australasia	Australia	Forest/woodland decline	1964	2004
Banfai, Daniel S., and David MJS Bowman. "Forty years of lowland monsoon rainforest expansion in Kakadu National Park, Northern Australia." Biological Conservation 131.4 (2006): 553-565.	2006	Australasia	Australia	Forest/woodland decline	1964	2004
Banfai, Daniel S., and David MJS Bowman. "Forty years of lowland monsoon rainforest expansion in Kakadu National Park, Northern Australia." Biological Conservation 131.4 (2006): 553-565.	2006	Australasia	Australia	Forest/woodland decline	1964	2004
Banfai, Daniel S., and David MJS Bowman. "Forty years of lowland monsoon rainforest expansion in Kakadu National Park, Northern Australia." Biological Conservation 131.4 (2006): 553-565.	2006	Australasia	Australia	Forest/woodland decline	1964	2004
Banfai, Daniel S., and David MJS Bowman. "Forty years of lowland monsoon rainforest expansion in Kakadu National Park, Northern Australia." Biological Conservation 131.4 (2006): 553-565.	2006	Australasia	Australia	Forest/woodland decline	1964	2004
Fensham, R.J. and Fairfax, R.J., 2005. Preliminary assessment of gidgee (Acacia cambagei) woodland thickening in the Longreach district, Queensland. The Rangeland Journal, 27(2), pp.159-168.	2005	Australasia	Australia	Forest/woodland decline	2005	2005
Fensham, R.J. and Fairfax, R.J., 2007. Drought-related tree death of savanna eucalypts: Species susceptibility, soil conditions and root architecture. Journal of Vegetation Science, 18(1), pp.71-80.	2007	Australasia	Australia	Forest/woodland decline	2004	2004
Fensham, R.J. and Holman, J.E., 1999. Temporal and spatial patterns in drought-related tree dieback in Australian savanna. Journal of Applied Ecology, 36(6), pp.1035-1050.	1999	Australasia	Australia	Forest/woodland decline	1992	1996
Fensham, R.J., Fairfax, R.J. and Ward, D.P., 2009. Drought-induced tree death in savanna. Global Change Biology, 15(2), pp.380-387.	2009	Australasia	Australia	Forest/woodland decline	1946	2002
Fensham, R.J., Fairfax, R.J. and Ward, D.P., 2009. Drought-induced tree death in savanna. Global Change Biology, 15(2), pp.380-387.	2009	Australasia	Australia	Forest/woodland decline	1990	2002

Hosking, G.P. and Hutcheson, J.A., 1988. Mountain beech (Nothofagus solandri var. cliffortioides) decline in the Kaweka Range, North Island, New Zealand. New Zealand Journal of Botany, 26(3), pp.393-400.	1988	Australasia	New Zealand	Forest/woodland decline	1984	1987
Hosking, G.P. and Kershaw, D.J., 1985. Red beech death in the Maruia Valley South Island, New Zealand. New Zealand Journal of Botany, 23(2), pp.201-211.	1985	Australasia	New Zealand	Forest/woodland decline	1978	1980
Sharp, B.R. and Bowmann, D.M.J.S. 2004. Net woody vegetation increase confined to seasonally inundated lowlands in an Australian tropical savanna,Victoria River District, Northern Territory. Austral Ecology, 29:667-683.	2004	Australasia	Australia	Forest/woodland decline	1948	1995
Gitlin, A.R., Sthultz, C.M., Bowker, M.A., Stumpf, S., Paxton, K.L., Kennedy, K., Muñoz, A., Bailey, J.K. and Whitham, T.G., 2006. Mortality gradients within and among dominant plant populations as barometers of ecosystem change during extreme drought. Conservation Biology, 20(5), pp.1477-1486.	2006	North America	United States	Forest/woodland decline	2000	2004
Gitlin, A.R., Sthultz, C.M., Bowker, M.A., Stumpf, S., Paxton, K.L., Kennedy, K., Muñoz, A., Bailey, J.K. and Whitham, T.G., 2006. Mortality gradients within and among dominant plant populations as barometers of ecosystem change during extreme drought. Conservation Biology, 20(5), pp.1477-1486.	2006	North America	United States	Forest/woodland decline	2000	2004
Gitlin, A.R., Sthultz, C.M., Bowker, M.A., Stumpf, S., Paxton, K.L., Kennedy, K., Muñoz, A., Bailey, J.K. and Whitham, T.G., 2006. Mortality gradients within and among dominant plant populations as barometers of ecosystem change during extreme drought. Conservation Biology, 20(5), pp.1477-1486.	2006	North America	United States	Forest/woodland decline	2000	2004
Gitlin, A.R., Sthultz, C.M., Bowker, M.A., Stumpf, S., Paxton, K.L., Kennedy, K., Muñoz, A., Bailey, J.K. and Whitham, T.G., 2006. Mortality gradients within and among dominant plant populations as barometers of ecosystem change during extreme drought. Conservation Biology, 20(5), pp.1477-1486.	2006	North America	United States	Forest/woodland decline	2000	2004
Gitlin, A.R., Sthultz, C.M., Bowker, M.A., Stumpf, S., Paxton, K.L., Kennedy, K., Muñoz, A., Bailey, J.K. and Whitham, T.G., 2006. Mortality gradients within and among dominant plant populations as barometers of ecosystem change during extreme drought. Conservation Biology, 20(5), pp.1477-1486.	2006	North America	United States	Forest/woodland decline	2000	2004
Gitlin, A.R., Sthultz, C.M., Bowker, M.A., Stumpf, S., Paxton, K.L., Kennedy, K., Muñoz, A., Bailey, J.K. and Whitham, T.G., 2006. Mortality gradients within and among dominant plant populations as barometers of ecosystem change during extreme drought. Conservation Biology, 20(5), pp.1477-1486.	2006	North America	United States	Forest/woodland decline	2000	2004
Guarín, A. and Taylor, A.H., 2005. Drought triggered tree mortality in mixed conifer forests in Yosemite National Park, California, USA. Forest ecology and management, 218(1-3), pp.229-244.	2005	North America	Unites States	Forest/woodland decline	1986	1992

Hogg, E.H., Brandt, J.P. and Kochtubajda, B., 2002. Growth and dieback of aspen forests in northwestern Alberta, Canada, in relation to climate and insects. Canadian Journal of Forest Research, 32(5), pp.823-832.	2002	North America	Canada	Forest/woodl and decline	1990	1997
Hogg, E.H., Brandt, J.P. and Michaelian, M., 2008. Impacts of a regional drought on the productivity, dieback, and biomass of western Canadian aspen forests. Canadian Journal of Forest Research, 38(6), pp.1373-1384.	2008	North America	Canada	Forest/woodl and decline	2002	2004
Jones, A.R.C. and Hendershot, W.H., 1989. Maple decline in Quebec: a discussion of possible causes and the use of fertilizers to limit damage. The Forestry Chronicle, 65(4), pp.280-287.	1989	North America	Eastern North America	Forest/woodl and decline	1980	1990
Kurz, W.A., Dymond, C.C., Stinson, G., Rampley, G.J., Neilson, E.T., Carroll, A.L., Ebata, T. and Safranyik, L., 2008. Mountain pine beetle and forest carbon feedback to climate change. Nature, 452(7190), p.987.	2008	North America	Canada	Forest/woodl and decline	2000	2006
Macomber, S.A. and Woodcock, C.E., 1994. Mapping and monitoring conifer mortality using remote sensing in the Lake Tahoe Basin. Remote sensing of environment, 50(3), pp.255-266.	1994	North America	Unites States	Forest/woodl and decline	1986	1992
Millar, C.I., Westfall, R.D. and Delany, D.L., 2007. Response of high-elevation limber pine (Pinus flexilis) to multiyear droughts and 20th-century warming, Sierra Nevada, California, USA. Canadian Journal of Forest Research, 37(12), pp.2508-2520.	2007	North America	Unites States	Forest/woodl and decline	1985	1995
Minnesota Department of Natural Resources. 2007. Federal conditions report 2007. 24 pp. http://fhm.fs.fed.us/fhh/fhh_07/mn_fhh_07.pdf	2007	North America	United States	Forest/woodl and decline	2004	2007
Mueller, R.C., Scudder, C.M., Porter, M.E., Talbot Trotter III, R., Gehring, C.A. and Whitham, T.G., 2005. Differential tree mortality in response to severe drought: evidence for long-term vegetation shifts. Journal of Ecology, 93(6), pp.1085-1093.	2005	North America	Unites States	Forest/woodl and decline	1996	1996
Negron, J.F., McMillin, J.D., Anhold, J.A. and Coulson, D., 2009. Bark beetle-caused mortality in a drought-affected ponderosa pine landscape in Arizona, USA. Forest Ecology and Management, 257(4), pp.1353-1362.	2009	North America	United States	Forest/woodl and decline	2001	2004
Olano, J.M. and Palmer, M.W., 2003. Stand dynamics of an Appalachian old-growth forest during a severe drought episode. Forest Ecology and Management, 174(1-3), pp.139-148.	2003	North America	Unites States	Forest/woodl and decline	1984	1989
Payette, S., 2007. Contrasted dynamics of northern Labrador tree lines caused by climate change and migrational lag. Ecology. 88, 770-780.	2007	North America	Canada	Forest/woodl and decline	~1700	present
Pratt, R.B., Jacobsen, A.L., Ramirez, A.R., Helms, A.M., Traugh, C.A., Tobin, M.F., Heffner, M.S., and Davis, S.D. (2014). Mortality of resprouting chaparral shrubs after a fire and during a record drought: physiological mechanisms and demographic	2014	North America	United States	Forest/woodl and decline	2007	2013

consequences. Global Chang Biology 20, 893–907.						
Pratt, R.B., Jacobsen, A.L., Ramirez, A.R., Helms, A.M., Traugh, C.A., Tobin, M.F., Heffner, M.S., and Davis, S.D. (2014). Mortality of resprouting chaparral shrubs after a fire and during a record drought: physiological mechanisms and demographic consequences. Global Chang Biology 20, 893–907.	2014	North America	United States	Forest/woodl and decline	2007	2013
Pratt, R.B., Jacobsen, A.L., Ramirez, A.R., Helms, A.M., Traugh, C.A., Tobin, M.F., Heffner, M.S., and Davis, S.D. (2014). Mortality of resprouting chaparral shrubs after a fire and during a record drought: physiological mechanisms and demographic consequences. Global Chang Biology 20, 893–907.	2014	North America	United States	Forest/woodl and decline	2007	2013
Pratt, R.B., Jacobsen, A.L., Ramirez, A.R., Helms, A.M., Traugh, C.A., Tobin, M.F., Heffner, M.S., and Davis, S.D. (2014). Mortality of resprouting chaparral shrubs after a fire and during a record drought: physiological mechanisms and demographic consequences. Global Chang Biology 20, 893–907.	2014	North America	United States	Forest/woodl and decline	2007	2013
Savage, M., 1997. The role of anthropogenic influences in a mixed-conifer forest mortality episode. Journal of Vegetation Science, 8(1), pp.95-104.	1997	North America	Unites States and Mexico	Forest/woodl and decline	1984	early 1990s
Starkey, D.A., Oliveria, F., Mangini, A. and Mielke, M., 2004. Oak decline and red oak borer in the interior Highlands of Arkansas an Missouri: natural phenomena, severe Occurrences. Gen. Tech. Rep. SRS-73. Asheville, NC: US Department of Agriculture, Forest Service, Southern Research Station. pp. 217-222.	2004	North America	United States	Forest/woodl and decline	1990	2002
Van Mantgem, P.J. and Stephenson, N.L., 2007. Apparent climatically induced increase of tree mortality rates in a temperate forest. Ecology Letters, 10(10), pp.909-916.	2007	North America	United States	Forest/woodl and decline	1983	2004
Van Mantgem, P.J., Stephenson, N.L., Byrne, J.C., Daniels, L.D., Franklin, J.F., Fulé, P.Z., Harmon, M.E., Larson, A.J., Smith, J.M., Taylor, A.H. and Veblen, T.T., 2009. Widespread increase of tree mortality rates in the western United States. Science, 323(5913), pp.521-524.	2009	North America	United States	Forest/woodl and decline	1955	2007
Venturas, M.D., MacKinnon, E.D., Dario, H.L., Jacobsen, A.L., Pratt, B., and Davis, S.D. (2016). Chaparral shrub hydraulic traits, size, and life history types relate to species mortality during California's historic drought of 2014. PloS ONE 11(7), e0159145.	2016	North America	United States	Forest/woodl and decline	2012	2014

Worrall, J.J., Egeland, L., Eager, T., Mask, R.A., Johnson, E.W., Kemp, P.A. and Shepperd, W.D., 2008. Rapid mortality of Populus tremuloides in southwestern Colorado, USA. Forest Ecology and Management, 255(3-4), pp.686-696.	2008	North America	United States	Forest/woodland decline	2005	2006
Donato, Daniel C., Brian J. Harvey, and Monica G. Turner. "Regeneration of montane forests 24 years after the 1988 Yellowstone fires: A fire-catalyzed shift in lower treelines?." *Ecosphere* 7.8 (2016): e01410.	2016	North America	United States	Forest/woodland decline	1988	2012
Syphard, A. D., Brennan, T. J., & Keeley, J. E. (2019). Extent and drivers of vegetation type conversion in Southern California chaparral. *Ecosphere*, *10*(7), e02796.	2019	North America	United States	Forest/woodland decline	1953	2016
Fettig, C. J., Mortenson, L. A., Bulaon, B. M., & Foulk, P. B. (2019). Tree mortality following drought in the central and southern Sierra Nevada, California, US. Forest Ecology and Management, 432, 164-178.	2019	North America	United States	Forest/woodland decline	2014	2017
Fettig, C. J., Mortenson, L. A., Bulaon, B. M., & Foulk, P. B. (2019). Tree mortality following drought in the central and southern Sierra Nevada, California, US. Forest Ecology and Management, 432, 164-178.	2019	North America	United States	Forest/woodland decline	2014	2017
Fettig, C. J., Mortenson, L. A., Bulaon, B. M., & Foulk, P. B. (2019). Tree mortality following drought in the central and southern Sierra Nevada, California, US. Forest Ecology and Management, 432, 164-178.	2019	North America	United States	Forest/woodland decline	2014	2017
Fettig, C. J., Mortenson, L. A., Bulaon, B. M., & Foulk, P. B. (2019). Tree mortality following drought in the central and southern Sierra Nevada, California, US. Forest Ecology and Management, 432, 164-178.	2019	North America	United States	Forest/woodland decline	2014	2017
Paddock III, W. A., Davis, S. D., Pratt, R. B., Jacobsen, A. L., Tobin, M. F., López-Portillo, J., & Ewers, F. W. (2013). Factors determining mortality of adult chaparral shrubs in an extreme drought year in California. Aliso: A Journal of Systematic and Evolutionary Botany, 31(1), 49-57.	2013	North America	United States	Forest/woodland decline	1998	2002
Venturas, M. D., MacKinnon, E. D., Dario, H. L., Jacobsen, A. L., Pratt, R. B., & Davis, S. D. (2016). Chaparral shrub hydraulic traits, size, and life history types relate to species mortality during California's historic drought of 2014. PloS one, 11(7), e0159145.	2016	North America	United States	Forest/woodland decline		
Pratt, R. B., Jacobsen, A. L., Ramirez, A. R., Helms, A. M., Traugh, C. A., Tobin, M. F., ... & Davis, S. D. (2014). Mortality of resprouting chaparral shrubs after a fire and during a record drought: physiological mechanisms and demographic consequences. Global change biology, 20(3), 893-907.	2014	North America	United States	Forest/woodland decline		
Syphard, A. D., Brennan, T. J., & Keeley, J. E. (2019). Drivers of chaparral type conversion to herbaceous vegetation in coastal Southern California. Diversity and Distributions, 25(1), 90-101.	2019	North America	United States	Forest/woodland decline	1943	2014

Barger, N. N., Archer, S. R., Campbell, J. L., Huang, C. Y., Morton, J. A., & Knapp, A. K. (2011). Woody plant proliferation in North American drylands: a synthesis of impacts on ecosystem carbon balance. Journal of Geophysical Research: Biogeosciences, 116(G4).	2011	North America	United States	Forest/woodland decline	1960	1983
Brandt, M., Hiernaux, P., Rasmussen, K., Tucker, C. J., Wigneron, J. P., Diouf, A. A., ... & Abel, C. (2019). Changes in rainfall distribution promote woody foliage production in the Sahel. Communications biology, 2(1), 1-10.	2019	Africa	Sahel	Grass cover loss	1987	2016
Brandt, M., Hiernaux, P., Rasmussen, K., Tucker, C. J., Wigneron, J. P., Diouf, A. A., ... & Abel, C. (2019). Changes in rainfall distribution promote woody foliage production in the Sahel. Communications biology, 2(1), 1-10.	2019	Africa	Sahel	Grass cover loss	1987	2016
Li, W., Buitenwerf, R., Munk, M., Amoke, I., Bøcher, P. K., & Svenning, J. C. (2020). Accelerating savanna degradation threatens the Maasai Mara socio-ecological system. Global Environmental Change, 60, 102030.	2020	Africa	Kenya	Grass cover loss	1985	2016
Venter, Z. S., Scott, S. L., Desmet, P. G., & Hoffman, M. T. (2020). Application of Landsat-derived vegetation trends over South Africa: Potential for monitoring land degradation and restoration. Ecological Indicators, 113, 106206.	2020	Africa	South Africa	Grass cover loss	1987	2013
BENTOUATI, A. and BARITEAU, M., Réflexions sur le déperissement du Cèdre de l'Atlas des Aurès (Algérie). Association Forêt Méditerranéenne, 14 rue Louis Astouin, 13002 MARSEILLE, France.	2006	Africa	Algeria	Forest/woodland decline	2000	2008
Eckhardt, H. C., Wilgen, B. W., & Biggs, H. C. (2000). Trends in woody vegetation cover in the Kruger National Park, South Africa, between 1940 and 1998. African Journal of Ecology, 38(2), 108-115.	2000	Africa	South Africa	Forest/woodland decline	1940	1998
El Abidine, A.Z., 2003. Forest decline in Morocco: causes and control strategy. Science et changements planetaires/Secheresse, 14(4), pp.209-218.	2003	Africa	Morocco	Forest/woodland decline	2002	2008
Foden, W., Midgley, G.F., Hughes, G., Bond, W.J., Thuiller, W., Hoffman, M.T., Kaleme, P., Underhill, L.G., Rebelo, A. and Hannah, L., 2007. A changing climate is eroding the geographical range of the Namib Desert tree Aloe through population declines and dispersal lags. Diversity and Distributions, 13(5), pp.645-653.	2007	Africa	Namibia	Forest/woodland decline	1904	2002
Goetze, D., Hörsch, B., & Porembski, S. (2006). Dynamics of forest–savanna mosaics in north-eastern Ivory Coast from 1954 to 2002. Journal of Biogeography, 33(4), 653-664.	2006	Africa	Guinea	Forest/woodland decline	1954	1996
Gonzalez, P., 2001. Desertification and a shift of forest species in the West African Sahel. Climate research, 17(2), pp.217-228.	2001	Africa	Senegal	Forest/woodland decline	1945	1993

Lwanga, J.S., 2003. Localized tree mortality following the drought of 1999 at Ngogo, Kibale National Park, Uganda. African Journal of Ecology, 41(2), pp.194-196.	2003	Africa	Uganda	Forest/woodland decline	1999	1999
Macgregor, S.D. and O'Connor, T.G., 2002. Patch dieback of Colophospermum mopane in a dysfunctional semi-arid African savanna. Austral Ecology, 27(4), pp.385-395.	2002	Africa	South Africa	Forest/woodland decline	1988	1992
Mapaure, I. N., & Campbell, B. M. (2002). Changes in miombo woodland cover in and around Sengwa Wildlife Research Area, Zimbabwe, in relation to elephants and fire. African Journal of Ecology, 40(3), 212-219.	2002	Africa	Zimbabwe	Forest/woodland decline	1958	1996
Mapaure, I. N., & Campbell, B. M. (2002). Changes in miombo woodland cover in and around Sengwa Wildlife Research Area, Zimbabwe, in relation to elephants and fire. African Journal of Ecology, 40(3), 212-219.	2002	Africa	Zimbabwe	Forest/woodland decline	1958	1996
Mapedza, E., Wright, J., & Fawcett, R. (2003). An investigation of land cover change in Mafungautsi Forest, Zimbabwe, using GIS and participatory mapping.Applied Geography, 23(1), 1-21.	2003	Africa	Zimbabwe	Forest/woodland decline	1976	1996
Mosugelo, D. K., Moe, S. R., Ringrose, S., & Nellemann, C. (2002). Vegetation changes during a 36-year period in northern Chobe National Park, Botswana.African Journal of Ecology, 40(3), 232-240.	2002	Africa	Botswana	Forest/woodland decline	1962	1998
O'Connor, T. G. (2001). Effect of small catchment dams on downstream vegetation of a seasonal river in semi-arid African savanna. Journal of Applied Ecology, 38(6), 1314-1325.	2001	Africa	South Africa	Forest/woodland decline	1991	1991
O'connor, T.G., 1998. Impact of sustained drought on a semi-arid Colophospermum mopane savanna. African Journal of Range & Forage Science, 15(3), pp.83-91.	1998	Africa	South Africa	Forest/woodland decline	1982	1997
Tafangenyasha, C. (1997). Tree loss in the Gonarezhou National Park (Zimbabwe) between 1970 and 1983. Journal of Environmental Management,49(3), 355-366.	1997	Africa	Zimbabwe	Forest/woodland decline	1970	1984
Tafangenyasha, C., 2001. Decline of the mountain acacia, Brachystegia glaucescens in Gonarezhou National Park, southeast Zimbabwe. Journal of Environmental Management, 63(1), pp.37-50.	2001	Africa	Zimbabwe	Forest/woodland decline	1970	1982
Tafangenyasha, C., 2001. Decline of the mountain acacia, Brachystegia glaucescens in Gonarezhou National Park, southeast Zimbabwe. Journal of Environmental Management, 63(1), pp.37-50.	2001	Africa	Zimbabwe	Forest/woodland decline	1991	1992
Van Langevelde, F., Van De Vijver, C. A., Kumar, L., Van De Koppel, J., De Ridder, N., Van Andel, J., ... & Rietkerk, M. (2003). Effects of fire and herbivory on the stability of savanna ecosystems. Ecology, 84(2), 337-350.	2003	Africa	Tanzania	Forest/woodland decline	1971	1996

Van Langevelde, F., Van De Vijver, C. A., Kumar, L., Van De Koppel, J., De Ridder, N., Van Andel, J., ... & Rietkerk, M. (2003). Effects of fire and herbivory on the stability of savanna ecosystems. Ecology, 84(2), 337-350.	2003	Africa	Tanzania	Forest/woodland decline	1971	1996
Viljoen, A.J., 1995. The influence of the 1991/92 drought on the woody vegetation of the Kruger National Park. Koedoe, 38(2), pp.85-97.	1995	Africa	South Africa	Forest/woodland decline	1991	1993
Ward, D., Hoffman, M. T., & Collocott, S. J. (2014). A century of woody plant encroachment in the dry Kimberley savanna of South Africa. African Journal of Range & Forage Science, (ahead-of-print), 1-15.	2014	Africa	South Africa	Forest/woodland decline	1919	2010
Brandt, M., Hiernaux, P., Rasmussen, K., Tucker, C. J., Wigneron, J. P., Diouf, A. A., ... & Abel, C. (2019). Changes in rainfall distribution promote woody foliage production in the Sahel. Communications biology, 2(1), 1-10.	2019	Africa	Sahel	Forest/woodland decline	1987	2016
Brandt, M., Hiernaux, P., Rasmussen, K., Tucker, C. J., Wigneron, J. P., Diouf, A. A., ... & Abel, C. (2019). Changes in rainfall distribution promote woody foliage production in the Sahel. Communications biology, 2(1), 1-10.	2019	Africa	Sahel	Forest/woodland decline	1987	2016
Li, W., Buitenwerf, R., Munk, M., Amoke, I., Bøcher, P. K., & Svenning, J. C. (2020). Accelerating savanna degradation threatens the Maasai Mara socio-ecological system. Global Environmental Change, 60, 102030.	2020	Africa	Kenya	Forest/woodland decline	1985	2016
Venter, Z. S., Scott, S. L., Desmet, P. G., & Hoffman, M. T. (2020). Application of Landsat-derived vegetation trends over South Africa: Potential for monitoring land degradation and restoration. Ecological Indicators, 113, 106206.	2020	Africa	South Africa	Forest/woodland decline	2004	2018
White, J. D. M., Jack, S. L., Hoffman, M. T., Puttick, J., Bonora, D., Visser, V., & February, E. C. (2016). Collapse of an iconic conifer: long-term changes in the demography of Widdringtonia cedarbergensis using repeat photography. BMC ecology, 16(1), 1-11.	2016	Africa	South Africa	Forest/woodland decline	1931	2013
Matusick, G., Ruthrof, K. X., Kala, J., Brouwers, N. C., Breshears, D. D., & Hardy, G. E. S. J. (2018). Chronic historical drought legacy exacerbates tree mortality and crown dieback during acute heatwave-compounded drought. Environmental Research Letters, 13(9), 095002.	2018	Australasia	Australia	Forest/woodland decline	2010	
Brouwers, N. C., Mercer, J., Lyons, T., Poot, P., Veneklaas, E., & Hardy, G. (2013). Climate and landscape drivers of tree decline in a Mediterranean ecoregion. *Ecology and Evolution*, *3*(1), 67-79.	2013	Australasia	Australia	Forest/woodland decline	2002	2008
Zhang, C., Wang, X., Li, J., & Hua, T. (2020). Identifying the effect of climate change on desertification in northern China via trend analysis of potential evapotranspiration and precipitation. *Ecological Indicators*, *112*, 106141.	2020	Asia	China	Grass cover loss	1990	2000

Zhang, C., Wang, X., Li, J., & Hua, T. (2020). Identifying the effect of climate change on desertification in northern China via trend analysis of potential evapotranspiration and precipitation. *Ecological Indicators*, *112*, 106141.	2020	Asia	China	Grass cover loss	1990	2000
Zhang, C., Wang, X., Li, J., & Hua, T. (2020). Identifying the effect of climate change on desertification in northern China via trend analysis of potential evapotranspiration and precipitation. *Ecological Indicators*, *112*, 106141.	2020	Asia	China	Grass cover loss	1990	2000
Mahmoudi, P., Kalim, D., & Amirmoradi, M. R. (2011). Investigation of Iran Vulnerability Trend to Desertification with approach of climate change. In Second International Conference on Environmental Science and Development IPCBEE; IACSIT Press: Singapore (Vol. 4, pp. 63-67).	2011	Asia	Iran	Grass cover loss	1976	2005
Mahmoudi, P., Kalim, D., & Amirmoradi, M. R. (2011). Investigation of Iran Vulnerability Trend to Desertification with approach of climate change. In Second International Conference on Environmental Science and Development IPCBEE; IACSIT Press: Singapore (Vol. 4, pp. 63-67).	2011	Asia	Iran	Grass cover loss	1976	2005
Barbosa, H. A., Kumar, T. L., & Silva, L. R. M. (2015). Recent trends in vegetation dynamics in the South America and their relationship to rainfall. *Natural Hazards*, *77*(2), 883-899.	2015	South America	Argentina	Grass cover loss	1998	2014
Barbosa, H. A., Kumar, T. L., & Silva, L. R. M. (2015). Recent trends in vegetation dynamics in the South America and their relationship to rainfall. *Natural Hazards*, *77*(2), 883-899.	2015	South America		Shrub/woodland cover gain	1998	2014
Javed, A., Jamal, S., & Khandey, M. Y. (2012). Climate change induced land degradation and socio-economic deterioration: a remote sensing and gis based case study from Rajasthan, India.	2012	Asia	India	Grass cover loss	1998	2010
Burrell, A. L., Evans, J. P., & De Kauwe, M. G. (2020). Anthropogenic climate change has driven over 5 million km 2 of drylands towards desertification. *Nature communications*, *11*(1), 1-11.	2020	Australia		Grass cover loss	1982	2015
Burrell, A. L., Evans, J. P., & De Kauwe, M. G. (2020). Anthropogenic climate change has driven over 5 million km 2 of drylands towards desertification. *Nature communications*, *11*(1), 1-11.	2020	Africa	Namibia	Grass cover loss	1982	2015

Table SM2.5: Key risks to terrestrial and freshwater ecosystems from climate change. Details of temperature levels for risk transitions for the burning embers diagram Figure 2.11. see 2.5.4

IPCC Risk Levels

Level	Undetectable (White)	Moderate (Yellow)	High (Red)	Very High (Purple)
Definition	No associated impacts are detectable and	Associated impacts are both detectable and attributable to climate change with at least	Severe and widespread impacts that are judged	Very high risk is indicated by all specific criteria for

	attributable to climate change.	*medium confidence*, also accounting for the other specific criteria for key risks.	to be high on one or more criteria for assessing key risks	key risks, including limited ability to adapt.

Key Risk – Biodiversity Risk due to climate change. Loss of species erodes ecosystem integrity, functioning, provisioning of services (including climate regulation, food and water) and resilience to extreme events and future climate change.

Risk Transition	**Global mean surface temperature change above pre-industrial period (°C)**		**Confidence**	**Description**
Undetectable to Moderate	minimum	0.6°C	*High*	
	median	0.08°C		Observations of the first species to lose >50% of range due to climate change, rendering them in the IUCN category of "endangered". Many local population extinctions observed in the most sensitive species, global extinction of species attributable to climate change first start being detected.
	maximum	1.0°C		
Moderate to High	minimum	0.875°C	*Medium*	
	median	1.58°C		> 10% of species are projected to lose >50% of their range. Increasing number of taxa that show high extinction risk (>10% of the species in the taxa), weighted by role the species in the taxa play in performing services to ecosystems and humans, e.g. pollinators, detritivores. This is 1000x natural background rates of species' extinctions
	maximum	2.025°C		
High to Very High	minimum	1.6°C	*Medium*	
	median	2.07°C		> 20% of species are projected to lose >50% of their range. Increasing number of taxa that now show greater than 20% of the species in the taxa at high risk of extinction.
	maximum	2.55°C		Above this warming level, risk of extinction rises non-linearly. In the worst-case scenario (10th percentile of the models at 4.5°C), many taxa show >50% of the species in that taxa at high risk of extinction.

Key Risk - Wildfire considerably degrades ecosystems, substantially increases carbon emissions, and increases illnesses and death of people

Risk Transition	**Global mean surface temperature change above pre-industrial period (°C)**		**Confidence**	**Description**
Undetectable to Moderate	minimum	0.6°C	*High*	Field research and statistical analyses have detected and attributed increases in the area burned by wildfire

Risk Transition	**Global mean surface temperature change above pre-industrial period (°C)**		**Confidence**	**Description**
				above natural levels (see references in description for maximum); Global mean surface temperature change of 0.6ºC in the 1990s, in the middle of the period of observed changes (IPCC 2018 SR15)
	median	0.75°C		Median between the minimum and maximum values.
	maximum	0.9°C		Field research and statistical analyses have detected and attributed increases in the area burned by wildfire above natural levels in western North America from 1984 to 2017 (Chapter 2.4.4.2.1, Abatzoglou and Williams 2016, Partain et al. 2016, Kirchmeier-Young et al. 2019, Mansuy et al. 2019); Increases in burned area detected in the Amazon, Australia, and Siberia from a combination of climate and non-climate factors (Chapter 2.4.4.2.3, Ponomarev et al. 2016, van Marle et al. 2017, da Silva et al. 2018, Lindenmayer and Taylor 2020); Wildfires in the Arctic are contributing to permafrost thaw and soil carbon release (Brown et al. 2015, Natali et al. 2019, Walker et al. 2019); These changes have already occurred at a temperature increase of 1.1 ± 0.1ºC between the periods 1850-1900 and 2006-2015 (IPCC 2018 SR15).
Moderate to High	minimum	1.5°C	*Medium*	Projected increases in burned area, fire frequency, or fire weather across extensive areas globally, lower estimate (Gonzalez et al. 2010, Moritz et al. 2012, Flannigan et al. 2013, Burton et al. 2018, Abatzoglou et al. 2019)
	median	2.0°C		Projected increases in burned area or fire frequency above natural levels on all continents due to anthropogenic climate change (Gonzalez et al. 2010, Moritz et al. 2012); emergence of anthropogenic signal from natural variation in fire weather for a third of global area (Flannigan et al. 2013, Knorr et al. 2016, Burton et al. 2018, Abatzoglou et al. 2019); increase of burned area in areas where fire had been rare or absent, particularly Arctic tundra (Lehtonen et al. 2016, Young et al. 2017) (Chapter 2.5.5.2)
	maximum	2.5°C		Projected increases in burned area, fire frequency, or fire weather across extensive areas globally, upper estimate (Gonzalez et al. 2010, Moritz et al. 2012, Flannigan et al. 2013, Burton et al. 2018, Abatzoglou et al. 2019)
High to Very High	minimum	3.0°C	*Medium*	Wildfire-induced conversion of up to half the area of Amazon rainforest to grassland, lower threshold estimates (Lenton et al. 2008, Salazar and Nobre 2010, Lyra et al. 2016)
	median	4.0°C		Wildfire-induced conversion of up to half the area of Amazon rainforest to grassland (Oyama and Nobre 2003, Sampaio et al. 2007, Lenton et al. 2008, Nepstad et al. 2008, Malhi et al. 2009, Salazar and Nobre 2010, Settele et al. 2014, Lyra et al. 2016,

Risk Transition	**Global mean surface temperature change above pre-industrial period (°C)**		**Confidence**	**Description**
				Zemp et al. 2017, Brando et al. 2020); up to doubling of burned area in areas where fire had been rare or absent, particularly the Amazon (Le Page et al. 2017, Brando et al. 2020) and Arctic tundra (Lehtonen et al. 2016, Veraverbeke et al. 2017) substantially increasing global carbon emissions (Chapter 2.4.4.4, 2.5.5.2)
	maximum	4.5°C		Wildfire-induced conversion of up to half the area of Amazon rainforest to grassland, higher threshold estimate (Lenton et al. 2008, Salazar and Nobre 2010, Lyra et al. 2016)

Key Risk - Anthropogenic climate change cause widespread death of trees, damage ecosystems, and reduce provision of water and other services to people

Risk Transition	**Global mean surface temperature change above pre-industrial period (°C)**		**Confidence**	**Description**
Undetectable to Moderate	minimum	0.3°C	*High*	Field research and statistical analyses have detected and attributed to anthropogenic climate change increases in tree mortality in temperate and tropical ecosystems in the period 1945-2007 (see references in description for maximum); Global mean surface temperature change of 0.3ºC in the 1970s, in the middle of the period of observed changes (IPCC 2018 SR15).
	median	0.6°C		Median between the minimum and maximum values.
	maximum	0.9°C		Field research and statistical analyses have detected and attributed to anthropogenic climate change increases in tree mortality in temperate and tropical ecosystems in the period 1945-2007 (van Mantgem et al. 2009, Gonzalez et al. 2012, le Polain de Waroux and Lambin 2012). Drought has induced these cases of tree mortality, with pest infestations and wildfire also causing much of the tree mortality in temperate forests. These changes have already occurred at a temperature increase of 0.9 ± 0.1ºC between the periods 1850-1900 and 2006-2015 (IPCC 2018 SR15). (Sections 2.4.4.3; 2.5.5.3). Numerous other cases of drought-induced tree mortality have been detected around the world (Allen et al. 2010, Allen et al. 2015, Bennett et al. 2015, Martinez-Vilalta et al. 2016, Greenwood et al. 2017, Hartmann et al. 2018), consistent with but not formally attributed to anthropogenic climate change.
Moderate to High	minimum	1°C	*Medium*	Approximate lower bound of projections of more extensive tree mortality (see references in description for median)
	median	1.5°C		Models project increasingly extensive drought-induced tree mortality at continued moderate temperature increases. In western North America, one-tenth of

Risk Transition	**Global mean surface temperature change above pre-industrial period (°C)**		**Confidence**	**Description**
				forest area is highly vulnerable to drought-induced mortality under RCP8.5 by 2050 (Buotte et al. 2019) and increased evapotranspiration in conifer forests increases the fraction of the area at risk of tree mortality 15-20% per degree Celsius {Goulden et al. 2019). In boreal forest, fire-induced tree mortality from climate change under RCP8.5 could reduce the extent of spruce forest (*Picea sp.*) 8-44% by 2100 (Pastick et al. 2017). (Section 2.5.5.3).
	maximum	2°C		Approximate upper bound of projections of more extensive tree mortality (see references in description for median).
High to Very High	minimum	2.5°C	*Medium*	Approximate lower bound of projections of tree mortality of half the area of forest biomes (see references in description for median)
	median	3.5°C		Models project risks of mortality of up to half of forest area in different biomes. Climate change under RCP8.5 could cause drought-induced tree mortality and the loss of half of Northern Hemisphere conifer forest area by 2100 (McDowell et al. 2016). In southeast France, the most extreme summer temperatures could increase post-fire mortality of many broadleaf and conifer species 50% (Dupire et al. 2019). In Amazon rainforests, a lack of buffering capacity for plant moisture during drought increases the risk of tree mortality and, combined with increased fire from climate change and deforestation, the possibility of a tipping point of massive forest dieback and a biome shift to grassland (Oyama and Nobre 2003, Sampaio et al. 2007, Nepstad et al. 2008, Malhi et al. 2009, Settele et al. 2014, Lyra et al. 2016, Zemp et al. 2017, Brando et al. 2020). In Guinean tropical deciduous forest in Africa, climate change under RCP8.5 could increase mortality 700% by 2100 or 400% under lower emissions (RCP4.5) (Claeys et al. 2019).
	maximum	4.5°C		Approximate upper bound of projections of tree mortality of half the area of forest biomes (see references in description for median)

Key Risk - Ecosystem carbon loss from tipping points of loss of tropical forest and Arctic permafrost

Risk Transition	**Global mean surface temperature change above pre-industrial levels °C**		**Confidence**	**Description**
Undetectable to Moderate	minimum	0.6°C	*Medium*	Primary tropical forest comprised a net source of carbon to the atmosphere, 2001-2019 (emissions 0.6 Gt y^{-1}, net 0.1 Gt y^{-1}) (Harris et al. 2021). Anthropogenic climate change has thawed Arctic

Risk Transition	Global mean surface temperature change above pre-industrial levels °C		Confidence	Description
				permafrost (Guo et al. 2020), carbon emissions 1.7 ± 0.8 Gt y^{-1}, 2003-2017 (Natali et al. 2019). (See more details in description for maximum); Global mean surface temperature change of 0.6ºC in 2000 (IPCC 2018 SR15)
	median	0.75°C		Median between the minimum and maximum values.
	maximum	0.9°C		Primary tropical forest comprised a net source of carbon to the atmosphere, 2001-2019 (emissions 0.6 Gt y^{-1}, net 0.1 Gt y^{-1}) (Harris et al. 2021). Amazon as a whole was a net carbon emitter, 2003-2008 (Exbrayat et al. 2015, Yang et al. 2018), from deforestation for agriculture and livestock (De Sy et al. 2015, 2019). Amazon deforestation emitted 0.17 ± 0.05 Gt y^{-1} carbon, 2001-2015 (Silva Junior et al. 2020); fires emitted 0.12 ± 0.14 Gt y^{-1} carbon, 2003-2015 (Aragao et al. 2018). Amazon carbon loss from deforestation and degradation 0.5 Gt y^{-1}, 2010-2019 (Qin et al. 2021). Intact old-growth Amazon rainforest may have become a net carbon source, 2010-2019 {Qin et al. 2021). Anthropogenic climate change has thawed Arctic permafrost (Guo et al. 2020), carbon emissions 1.7 ± 0.8 Gt y^{-1}, 2003-2017 (Natali et al. 2019). These changes have already occurred at a temperature increase of 0.9ºC between the periods 1850-1900 and 2006-2015 (IPCC 2018 SR15).
Moderate to High	minimum	1.5°C	*Medium*	Limiting the global temperature increase to 1.5ºC, compared to 2ºC could reduce projected permafrost CO_2 losses by 2100 by 24.2 Gt C (median) (Comyn-Platt et al. 2018).
	median	2°C		Mean temperature increase of 2ºC could reduce permafrost area ~15% by 2100 (Comyn-Platt et al. 2018) and emit 20-58 Gt (von Deimling et al. 2015), 46–51 Gt (Comyn-Platt et al. 2018), 27-100 Gt (Schaefer et al. 2014) carbon by 2100. Globally, most soil carbon emissions would come from Arctic tundra, with climate change under RCP8.5 causing a soil carbon loss of 55 ± 50 Gt carbon by 2050, increasing atmospheric CO_2 by 25 ppm (Crowther et al. 2016). Wildfire-induced conversion of Amazon rainforest area to grassland (Lenton et al. 2008, Salazar and Nobre 2010, Lyra et al. 2016, Nobre et al. 2016, Boulton et al. 2017, Zemp et al. 2017, Marengo et al. 2018) of approximately 5% at 2ºC increase (Lyra et al. 2016), much of Amazon evergreen to deciduous forest 2-3ºC (Salazar and Nobre 2010).
	maximum	3°C		Much of Amazon evergreen to deciduous forest 2-3ºC (Salazar and Nobre 2010).
High to Very High	minimum	3°C	*Low*	Under RCP8.5, models project potential permafrost carbon losses by 2100 of 28–113 Gt (Koven et al. 2015), 11–143 Gt (Gasser et al. 2018), 42-141 Gt (von Deimling et al. 2015), 37–170 Gt (Schuur et al. 2015),

Risk Transition	Global mean surface temperature change above pre-industrial levels °C		Confidence	Description
				or 35-205 Gt (Schaefer et al. 2014) carbon, potentially increasing global average temperatures 0.29 ± 0.21ºC (Schaefer et al. 2014). Lower bound of temperature projection of RCP8.5 (IPCC 2013 AR5 WG I).
	median	4°C		Under RCP8.5, models project potential permafrost carbon losses by 2100 of 28–113 Gt (Koven et al. 2015), 11–143 Gt (Gasser et al. 2018), 42-141 Gt (von Deimling et al. 2015), 37–170 Gt (Schuur et al. 2015), or 35-205 Gt (Schaefer et al. 2014) carbon, potentially increasing global average temperatures 0.29 ± 0.21ºC (Schaefer et al. 2014). Wildfire-induced conversion of up to half the area of Amazon rainforest to grassland (Oyama and Nobre 2003, Sampaio et al. 2007, Nepstad et al. 2008, Malhi et al. 2009, Settele et al. 2014, Lyra et al. 2016, Zemp et al. 2017, Brando et al. 2020). This could occur at a 4-5ºC temperature increase above the pre-industrial period (Salazar and Nobre 2010). The potentially abrupt nature of this and its fundamental impact on global biogeochemistry mark the melting of permafrost as a tipping point (Schaefer et al. 2014).
	maximum	5°C		Amazon forest dieback could occur at a 4-5ºC temperature increase above the pre-industrial period (Salazar and Nobre 2010).

Key Risk – Ecosystem structure change

Risk Transition	Global mean surface temperature change above pre-industrial period (°C)		Confidence	Description
Undetectable to Moderate	minimum	0.5°C	*High*	
	median	1.5°C		Landscape and larger scale shifts in ecosystem structure and function. Changes attributable to climate change or interactions with changing disturbance regime, climate and rising CO_2 already observed at 0.5ºC increase, with shifts initially detected in boreal forests, tundra, and tropical grasslands
	maximum	3.0°C		
Moderate to High	minimum	2.0°C	*Medium*	
	median	3.2°C		Landscape and larger scale shifts in ecosystem structure and function. Global observations that agree with future projections with at least 10% of the area of key ecosystems affected, from Box 2.1. *Medium confidence* because existing observations and projections are not available for all biomes.
	maximum	4.5°C		

Risk Transition	**Global mean surface temperature change above pre-industrial period (°C)**		**Confidence**	**Description**
High to Very High	minimum	3.0°C	*Medium*	
	median	4.5°C		Increasing risk of landscape and larger scale shifts in ecosystem structure and function. Most information derived for tropical forest, boreal forest, savannas, and tundra. More than 50% of several ecosystems may experience shifts in structure and function.
	maximum	5.0°C		

Table SM2.6: References used to create the Cross-Chapter Box ILLNESS Table 1, in Chapter 2, by region

	Cholera	**Dengue**	**Malaria**
Global	(Escobar et al., 2015; Nichols et al., 2018; Watts et al., 2019)	(Campbell et al., 2015; Guzman and Harris, 2015)	(Gething et al., 2010; Phillips et al., 2017; Organization, 2020)
Africa	(Mendelsohn and Dawson, 2008; Paz, 2009; Nkoko et al., 2011; Reyburn et al., 2011; Magny et al., 2012; Jutla et al., 2013a; Rebaudet et al., 2013; Jutla et al., 2015; Leckebusch and Abdussalam, 2015; Sigudu et al., 2015; Moore et al., 2017; Watts et al., 2019)	(Caldwell et al., 2021)	(Hay et al., 2002; Pascual et al., 2006; Alonso et al., 2011; Omumbo et al., 2011; Chaves et al., 2012; Siraj et al., 2014; Bhatt et al., 2015; Boyce et al., 2016; Shah et al., 2019; Abiodun et al., 2020; Chirombo et al., 2020; Makinde and Abiodun, 2020; Matthew, 2020; Siya et al., 2020; Kassam et al., 2021)
Asia	(Sack et al., 2003; Agtini et al., 2005; Huq et al., 2005; Koelle et al., 2005; Emch et al., 2008; Magny et al., 2008; Emch et al., 2010; Hashizume et al., 2010; Goel and Jiang, 2011; Jutla et al., 2011; Akanda et al., 2013; Ali et al., 2013; Jutla et al., 2013a; Jutla et al., 2013b; Yue et al., 2014; Xu et al., 2016; Roobthaisong et al., 2017; Watts et al., 2019; Campbell et al., 2020)	(Nagao et al., 2003; Chakravarti and Kumaria, 2005; Kanchana et al., 2005; Thammapalo et al., 2005; Bangs et al., 2006; Arcari et al., 2007; Wu et al., 2007; Dahal, 2008; Halide and Ridd, 2008; Nagao et al., 2008; Hsieh and Chen, 2009; Lu et al., 2009; Wu et al., 2009; Hii et al., 2012; Dhimal et al., 2014a; Dhimal et al., 2014b; Dhimal et al., 2015a; Dhimal et al., 2015b; Xiang et al., 2017; Acharya et al., 2018; Li et al., 2019; Tuladhar et al., 2019; Adhikari and Subedi, 2020; Gyawali et al., 2020; Liu et al., 2020; Metelmann et al., 2021; Riad et al., 2021; Seah et al., 2021)	(Dhimal et al., 2014a; Dhimal et al., 2014c; Dhimal et al., 2015a; Emeto et al., 2020; Kumar et al., 2020; Wangdi et al., 2020; Faradiba, 2021; Sri Rejeki et al., 2021)
Australasia	(Watts et al., 2019)	(Bi et al., 2001; Kearney et al., 2009; Hu et al., 2010; Akter et al., 2020)	
Central America	(Watts et al., 2019)	(Herrera-basto et al., 1992; Lozano-Fuentes et al., 2012; Colón-González et al., 2013; Hernández-Ávila et al., 2013; Stewart-Ibarra and Lowe, 2013; Stewart-Ibarra et al., 2013; Dantés et al., 2014; Lowe et al.,	(Pinault and Hunter, 2011; Manguin and Dev, 2018; Ferreira and Castro, 2019; Fletcher et al., 2020)

		2017; Watts et al., 2020; Caldwell et al., 2021)	
South America	(Gil et al., 2004; Martinez-Urtaza et al., 2008; Ryan et al., 2018; Watts et al., 2019)	(Estallo et al., 2020; Robert et al., 2020)	(Siraj et al., 2014; Manguin and Dev, 2018; Ferreira and Castro, 2019; Laneri et al., 2019; Douine et al., 2020; Rozo, 2020; Grillet et al., 2021)
Europe	(Vezzulli et al., 2012; Vezzulli et al., 2016; Watts et al., 2019)	(Bouzid et al., 2014; Robert et al., 2020)	(Fischer et al., 2020; Boualam et al., 2021)
North America	(Louis Valérie et al., 2003; Vezzulli et al., 2016; Watts et al., 2019)	(Añez and Rios, 2013; Fredericks and Fernandez-Sesma, 2014; Butterworth et al., 2017; Lowe et al., 2018; Robert et al., 2019; Robert et al., 2020; Watts et al., 2020)	
Small Islands	(Jutla et al., 2013b; Alam et al., 2014; Watts et al., 2019)	(Morin et al., 2015)	(Ferreira and Castro, 2019)

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