ENVIRONMENTAL RESEARCH
LETTERS

PURPOSE-LED PUBLISHING™

Part of the ENVIRONMENTAL RESEARCH SERIES

TOPICAL REVIEW • OPEN ACCESS

Biophysical effects of land cover changes in West Africa: a systematic review

To cite this article: Abdel Nassirou Yahaya Seydou *et al* 2025 *Environ. Res. Lett.* **20** 073001

ENVIRONMENTAL RESEARCH
LETTERS

CrossMark

OPEN ACCESS

RECEIVED
12 November 2024

REVISED
6 May 2025

ACCEPTED FOR PUBLICATION
22 May 2025

PUBLISHED
9 June 2025

TOPICAL REVIEW

Biophysical effects of land cover changes in West Africa: a systematic review

Abdel Nassirou Yahaya Seydou[1,2,*], Souleymane Sy[3,*], Benjamin Quesada[4], Jan Bliefernicht[3], Kiril Manevski[5,6], Leonard K Amekudzi[7], Emmanuel K Appiah-Adjei[8], Kehinde O Ogunjobi[9], Bouba Traore[10], Charles Gyamfi[11] and Harald Kunstmann[2,3,12,*]

1 WASCAL Graduate Research Programme on Climate Change and Land Use, Department of Civil Engineering, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana
2 Institute of Meteorology and Climate Research, Karlsruhe Institute of Technology, Campus Alpin, Garmisch-Partenkirchen, Germany
3 Institute of Geography, Chair of Regional Climate and Hydrology, University of Augsburg, Augsburg, Germany
4 Earth System Science Program, School of Sciences and Engineering, Universidad del Rosario, Bogotá D.C., Colombia
5 Department of Agroecology, Aarhus University, Centre for Circular Bioeconomy, Tjele, Denmark
6 iClimate—Aarhus University Interdisciplinary Centre for Climate Change, Roskilde, Denmark
7 Department of Meteorology and Climate Science, KNUST, Kumasi, Ghana
8 Department of Geological Engineering, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana
9 Competence Centre, West African Science Service Centre on Climate Change and Adapted Land Use (WASCAL), Ouagadougou, 9507, Burkina Faso
10 International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Niamey BP 12404, Niger
11 Department of Civil Engineering, Faculty of Civil and Geo-Engineering, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana
12 Center for Climate Resilience, University of Augsburg, Augsburg, Germany
* Authors to whom any correspondence should be addressed.

E-mail: yahaya.a@edu.wascal.org, souleymane.sy@uni-a.de and harald.kunstmann@kit.edu

Keywords: land use, land cover change, deforestation, afforestation, climate modeling, PRISMA, West Africa

Supplementary material for this article is available online

Abstract

West Africa is undergoing rapid agricultural intensification driven by population growth, leading to significant anthropogenic land use and land cover change (LCC), including both deforestation and afforestation. These changes can profoundly affect the regional climate system by altering the surface energy balance, moisture fluxes, and atmospheric circulation, potentially exacerbating the vulnerability of human, ecological, and economic systems. Despite the ability of climate models to simulate LCC impacts, considerable uncertainties remain, particularly in simulations of precipitation and temperature responses. This study provides the first multidisciplinary systematic review of LCC impacts in West Africa. Data from 26 selected publications were eventually synthesized from an initial pool of nearly 6000 studies. Results indicate that deforestation generally contributes to regional warming, with significant historical temperature increases of $+0.26 \pm 0.12$ °C and projected increases of $+0.88 \pm 0.25$ °C under the future scenarios. Conversely, afforestation could have significantly cooled the climate, lowering temperatures by -0.24 ± 0.14 °C historically and -0.22 ± 0.14 °C in future scenarios, without even accounting for carbon sequestration. Deforestation decreases regional precipitation by 80 ± 58 mm yr^{-1} historically and -55 ± 102 mm yr^{-1} in future scenarios, while large-scale afforestation could substantially reduce droughts with increased precipitation, averaging $+40 \pm 67$ mm yr^{-1} historically and 80 ± 58 mm yr^{-1} in future scenarios. These results emphasize the need to integrate LCC-induced climate effects into land-based mitigation strategies, climate policy, and assessment frameworks.

1. Introduction

West Africa is experiencing rapid population growth associated with significant agricultural intensification (Van Bavel 2013, Bliefernicht *et al* 2018, Iyakaremye *et al* 2021a, Potapov *et al* 2022). Those anthropogenic land use and land-cover change (LCC) can have a significant impact on local, regional, and global climates by mainly altering atmospheric dynamics through two distinct processes: modifications in the net flux of greenhouse gases, such as CO_2, resulting from changes in vegetation and soil carbon (biogeochemical effects); and variations in the surface energy budget mediated by albedo, evapotranspiration, and surface roughness (biophysical effects) (Bonan 2008, Bathiany *et al* 2010, Mahmood *et al* 2014, Perugini *et al* 2017, Guug *et al* 2025).

LCC can also influence hydrology to an extent comparable to climate change at the regional scale (e.g. Araza *et al* 2021, Kayitesi *et al* 2022). However, its quantification remains limited, with potentially large uncertainties. Understanding LCC impacts and land–atmosphere interactions is crucial to assessing future climate changes (Wulfmeyer *et al* 2014, Harper *et al* 2018, Duveiller *et al* 2020, Roe *et al* 2021). In other words, enhanced representation of both the spatial and temporal dimensions of LCC is essential for a deeper understanding of human impact on the natural environment and climate (Roy *et al* 2015). To address these issues, Earth System Models (ESMs) and their land modeling components, such as dynamic global vegetation models, are used tools for global/regional scale analyses of LCC effects on climate (De Noblet-Ducoudré *et al* 2012, Sy *et al* 2017). These assessments are typically based on comparing simulations with and without LCC (Bonan 2008, Pitman *et al* 2009, Boisier *et al* 2012, De Noblet-Ducoudré *et al* 2012, Sy *et al* 2017, Sy and Quesada 2020). However, large uncertainties typically hinder this modeling approach in the numerical results due to the simplified process description (De Noblet-Ducoudré *et al* 2012, Rounsevell *et al* 2014, Lejeune *et al* 2017, Sy *et al* 2017, Davin *et al* 2020, Glotfelty *et al* 2021). For instance, the influence of LCC on precipitation in these numerical experiments remains highly uncertain due to the presence of low signal-to-noise ratios (Laux *et al* 2017).

For regions with extensive LCC, many studies have reported biophysical decreases in annual mean temperature of a magnitude similar to the concomitant increase in GHGs (Boisier *et al* 2012, De Noblet-Ducoudré *et al* 2012, Sy *et al* 2017). However, considerable disagreement remains in model results when simulating precipitation and temperature responses to LCC (Pitman *et al* 2009, De Noblet-Ducoudré *et al* 2012, Sy *et al* 2017, Sy and Quesada 2020, Glotfelty *et al* 2021). This is particularly true in West Africa, where research is often based on simulations with coarse resolution (e.g. Boone *et al* 2016, Sy *et al* 2017, Glotfelty *et al* 2021, Smiatek and Kunstmann 2023) and/or limited to a single climate model (e.g. Diba *et al* 2018, Camara *et al* 2022). Model uncertainties could be partly alleviated by improving the realism of the physically interconnected processes at the surface-atmosphere interface and a better description of these processes in state-of-the-art land surface models (De Noblet-Ducoudré *et al* 2012, Boone *et al* 2016, Sy *et al* 2017, Glotfelty *et al* 2021). The debates on the uncertainties related to the sign and the magnitude of the net effects of LCC on local/regional climate in model responses are ongoing and have been addressed in several papers (Pitman *et al* 2009, 2012, Avila *et al* 2012, Christidis *et al* 2013, Mahmood *et al* 2014, Findell *et al* 2017, Perugini *et al* 2017, Quesada *et al* 2017, Sy *et al* 2017, Lejeune *et al* 2018, Li Qiuping *et al* 2018, Chen and Dirmeyer 2019, Sy and Quesada 2020, Glotfelty *et al* 2021). Furthermore, the net effects of LCC on local/regional climate mainly depend on the type of LCC, its intensity, and local climate conditions (Mahmood *et al* 2014, Perugini *et al* 2017).

For instance, deforestation in tropical regions leads to a net global warming effect due to reduced evapotranspiration, which outweighs the cooling effect caused by a higher albedo (Perugini *et al* 2017). Conversely, at higher latitudes, the impact of deforestation is reversed, resulting in a net cooling effect due to the increased presence of high-albedo snow resulting from the conversion of tall vegetation to cropland/grassland or rapid urbanization (Mahmood *et al* 2014, Perugini *et al* 2017). The magnitude of the impact of deforestation depends on the spatial scale of the change. It also depends on the type of removed natural vegetation (Sy *et al* 2017). Consequently, numerous studies have recommended caution when attributing and assessing the effects of historical and future LCC due to the lack of a comprehensive, systematic assessment and limited agreement among model results (Pitman *et al* 2009, Pielke *et al* 2011, IPCC-SREX 2012, Mahmood *et al* 2014, Perugini *et al* 2017, Quesada *et al* 2017, Spracklen *et al* 2018, IPCC-SRCCL 2019, Sy and Quesada 2020).

Moreover, West Africa is a region particularly vulnerable to socio-economic, climatic and land use threats: (i) since the decade of the 80s, regional heatwaves have become hotter, longer and more widespread, and increasing trends in extreme heavy precipitation and droughts have been observed (Trisos *et al* 2022); (ii) West Africa is considered as a worldwide hotspot of land–atmosphere interactions (Koster *et al* 2004), with increasing population density (Iyakaremye *et al* 2021b), high water stress and land degradation (Sylla *et al* 2015); (iii) land cover dynamics are huge: the area of human-dominated land cover categories more than doubled in 40 years (Herrmann *et al* 2020), (iv) rain-fed agriculture is the main source of employment and income, but maize and wheat yields as well as agricultural productivity growth have decreased in the last decades mainly in response to climate change (Trisos *et al* 2022, Arfasa *et al* 2024, Waongo *et al* 2024); (v) irrigation demand in West Africa is expected to triple by 2050, a matter largely modulated by climate and LCC (Arfasa *et al* 2024), (vi) under the SSP2-4.5 and SSP5-8.5 future scenarios, Iyakaremye *et al* (2021a) indicate that temperature extremes are expected to intensify in Africa, with projected increases ranging from 0.25 °C to 1.8 °C under SSP2-4.5 and from 0.6 °C to 4 °C under SSP5-8.5. West Africa is identified as one of the regions projected to warm faster than the other regions, with large precipitation uncertainties driven in particular by different land–atmosphere interaction representations (Sylla *et al* 2016b, Sy *et al* 2017, Sy and Quesada 2020, Trisos *et al* 2022). Moreover, several studies have also already advocated for a more comprehensive assessment of the impact of LCC in the West Africa (Abiodun *et al* 2008, Sy *et al* 2017, 2024, Achugbu *et al* 2023, Mwanthi *et al* 2023, Smiatek and Kunstmann 2023, Ingrosso and Pausata 2024). These studies agree that the full scope of regional/local climate impacts of anthropogenic LCC remains challenging due to the high level of uncertainties surrounding quantifying these impacts, making it difficult to provide a clear message that can be effectively utilized in developing regional/local climate mitigation and adaptation strategies.

In the context of global warming mitigation, afforestation has been widely proposed as a key land-based strategy (Cook-Patton *et al* 2020, Doelman *et al* 2020, Duveiller *et al* 2020, Palmer 2021). In West Africa, large-scale initiatives such as the Great Green Wall have been launched to address climate change and land degradation (Smiatek and Kunstmann 2023, Ingrosso and Pausata 2024). This ambitious project aims to restore approximately 100 million hectares of forest by 2030 (UNCCD 2024). However, climate change mitigation policies, including reducing emissions from deforestation and forest degradation (REDD+), primarily focus on biogeochemical mechanisms like carbon sequestration, often overlooking the biophysical effects of afforestation. While biogeochemical processes are well integrated into global climate policies such as the Paris Agreement, biophysical effects—such as changes in surface albedo, evapotranspiration, and energy fluxes—are frequently neglected despite their significant regional impacts (Mahmood *et al* 2014, Perugini *et al* 2017, Sy *et al* 2017, Spracklen *et al* 2018, Duveiller *et al* 2020, Sy and Quesada 2020). Although climate models have significantly advanced our understanding of the potential impacts of afforestation on local and regional climates (Bonan 2008, Perugini *et al* 2017), debates persist regarding the net climatic effects of afforestation (Perugini *et al* 2017, Duveiller *et al* 2018a, Breil *et al* 2021, Arnault *et al* 2023, Ingrosso and Pausata 2024). The biophysical effects of afforestation, for instance, can either enhance or counteract the cooling effects associated with carbon sequestration (Bala *et al* 2007, Pongratz *et al* 2010, Arora and Montenegro 2011, Windisch *et al* 2021). Specifically, afforestation may induce radiative surface warming due to the lower albedo of forested areas, while non-radiative cooling effects could arise from increased heat dissipation and enhanced evapotranspiration (Bonan 2008, Duveiller *et al* 2018b).

Here, using a multidisciplinary systematic review following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol (Moher *et al* 2009) (see methods), this study provides a comprehensive analysis of the global literature on the regional biophysical impacts of LCC in West Africa to establish robust messages and associated uncertainties. This review stands apart from previous studies (Mahmood *et al* 2014, Perugini *et al* 2017) by strictly adhering to PRISMA eligibility criteria (Enu *et al* 2023), encompassing peer-reviewed scientific articles, books, and book chapters published from 1975 to 2023. Notably, this review examines historical and future model-based simulation results on the effects of LCC in West Africa. It also aims to provide policymakers with the critical evidence needed to assess the importance of the biophysical impacts of LCC, which are frequently overlooked despite their substantial regional/local effects (Mahmood *et al* 2014, Perugini *et al* 2017, Spracklen *et al* 2018, Duveiller *et al* 2020).

2. Data and methods

2.1. Search and selection strategy

The eligibility criteria outlined in the PRISMA guidelines were employed to systematically review the peer-reviewed literature on LCC biophysical impacts over West Africa. It is worth noting that West Africa was chosen due to its tropical location and ongoing agricultural intensification (Bliefernicht *et al* 2018, Potapov *et al* 2022), highlighting the potential benefits of afforestation policies within climate-smart agriculture (Rosenstock *et al* 2016). PRISMA was primarily designed for systematic reviews of studies evaluating the effects of health interventions (Moher *et al* 2009). Nevertheless, it remains widely utilized as a systematic review method in climate impact studies (e.g. Harper *et al* 2021, Carr *et al* 2022, Mensah *et al* 2022, Fiorenza *et al* 2023, Petersson-Bloom *et al* 2023).

As a preliminary step, the systematic review was conducted to select peer-reviewed scientific articles, books, and book chapters that specifically examine changes in surface air temperature and precipitation resulting from explicit LCC transition scenarios in West Africa and were published between 1 January 1975, and 30 April 2023. To achieve this, a variety of specific keywords, synonyms, search phrases, and strategies are employed tailored to each database/-portal (e.g. Web of Science, Scopus, Google Scholar, and the WASCAL library; see table S3) to identify relevant studies focusing on biophysical LCC (deforestation and afforestation) impact on regional climate in West Africa. Due to the sensitivity of search engines and portals to the order of search keywords, a range of keywords for each database source was also utilized (see table S3).

2.2. Selection criteria and data extraction

This study focuses on evidence from studies utilizing LCC model-based outputs at regional or country scales in West Africa. However, we have included the values provided for each region in the overall average for studies such as Smiatek and Kunstmann (2023), which cover the entire Sahel divided into three distinct regions. This approach ensures a comprehensive representation of data relevant to West Africa. Nevertheless, we acknowledge certain limitations arising from the lack of standardized definitions for the West African region in ESMs, as highlighted in previous studies (Boone *et al* 2016, Sy *et al* 2017, Sy and Quesada 2020, Glotfelty *et al* 2021, Achugbu *et al* 2023, Mwanthi *et al* 2023). While eddy-covariance flux towers and field experiments can provide local-scale insights into LCC effects (Bliefernicht *et al* 2018), they were excluded from this study due to their limited representativeness at the regional scale. Additionally, the reviewed literature includes only LCC-modeling-based articles because of data scarcity, limited *in-situ* measurements, and regional observation/satellite-driven assessments in this area. Moreover, this systematic review focused its primary emphasis on surface air temperature and precipitation variables for two significant reasons: (i) they constitute the primary variables of interest for policymakers at both local and regional levels, and (ii) they result as comprehensive indicators of biophysical influences on climate due to their responses to both biophysical radiative and non-radiative effects (Duveiller *et al* 2020, Sy *et al* 2024). We also focused on modifications of the main biophysical characteristics of the land surface, such as changes in leaf area index (LAI) and surface albedo, which ultimately result in changes in energy, moisture, and momentum fluxes (Davin and Noblet-Ducoudre´, 2010, De Noblet-Ducoudré *et al* 2012, Sy *et al* 2017). An overview of all inclusion and exclusion criteria used for each study is provided in table S1 and figure 1. The selection criteria primarily emphasize studies published in English and cited papers specifically within West Africa. The title and abstract were assessed to determine their relevance to our objectives. Subsequently, we thoroughly reviewed the full papers to extract all quantitative model output results, model types, considered study area, simulation period, published year, and LCC scenarios (see tables 1 and S2 for more details).

2.3. Data screening

Different combinations of search keywords relevant to LCC model-based studies (refer to table S3) were utilized in the search process. Duplicate articles were removed, and only peer-reviewed and cited English-language articles were included. The systematic review process followed a structured approach for both inclusion and exclusion of articles, as illustrated in figure 1. The initial database search yielded nearly 6000 articles ($n = 5986$). After conducting eligibility screening based on title, research area, and abstract, the number of articles was reduced to 485. Subsequently, some papers were excluded for reasons of unscientific articles or reviews or lack of quantitative data on LCC impact and/or not a model-based study in West Africa. In the final step, a total of 26 articles remained, from which the values presented in this paper were systematically extracted. These values were obtained through a careful, step-by-step review of the selected studies directly from the main text, tables, or supplementary materials. This rigorous approach ensured the accuracy and reliability of the data used in our analysis. To ensure impartiality, these processes were repeated three times (see figure 1, tables S1 and S3). Additionally, as shown in table S2, out of the initial 26 articles that passed the data screening and selection criteria, 22 provided model results on changes in surface air temperature, 25 on precipitation, 12 on surface albedo, and 4 on LAI. It is worth noting that among the selected articles, some have investigated the biophysical effects of LCC using a single model (e.g. Wang *et al* 2015, Achugbu *et al* 2023), while others employed multi-model ensemble simulations (e.g. 5 global climate models (GCMs) for Boone *et al* 2016; 4 RCMs for Glotfelty *et al* 2021; and 7 GCMs for, Sy *et al* 2017), which allow us further to discuss the uncertainties and the various mechanisms at play.

Furthermore, modeling studies were categorized under different explicit LCC scenarios. Specifically, model results were classified into two primary LCC categories: (i) deforestation scenarios (referred to as ‘Deforestation’), where total or partial fractions of forest cover are removed or replaced with another land cover type (see Charney 1975, Zheng and Eltahir 1997, Abiodun *et al* 2008, Wang *et al* 2015, Boone *et al* 2016, Sy *et al* 2017, Ji *et al* 2015, Chilukoti and Xue 2020, Sy and Quesada 2020, Glotfelty *et al* 2021, Duku and Hein 2021, Obahoundje *et al* 2021,

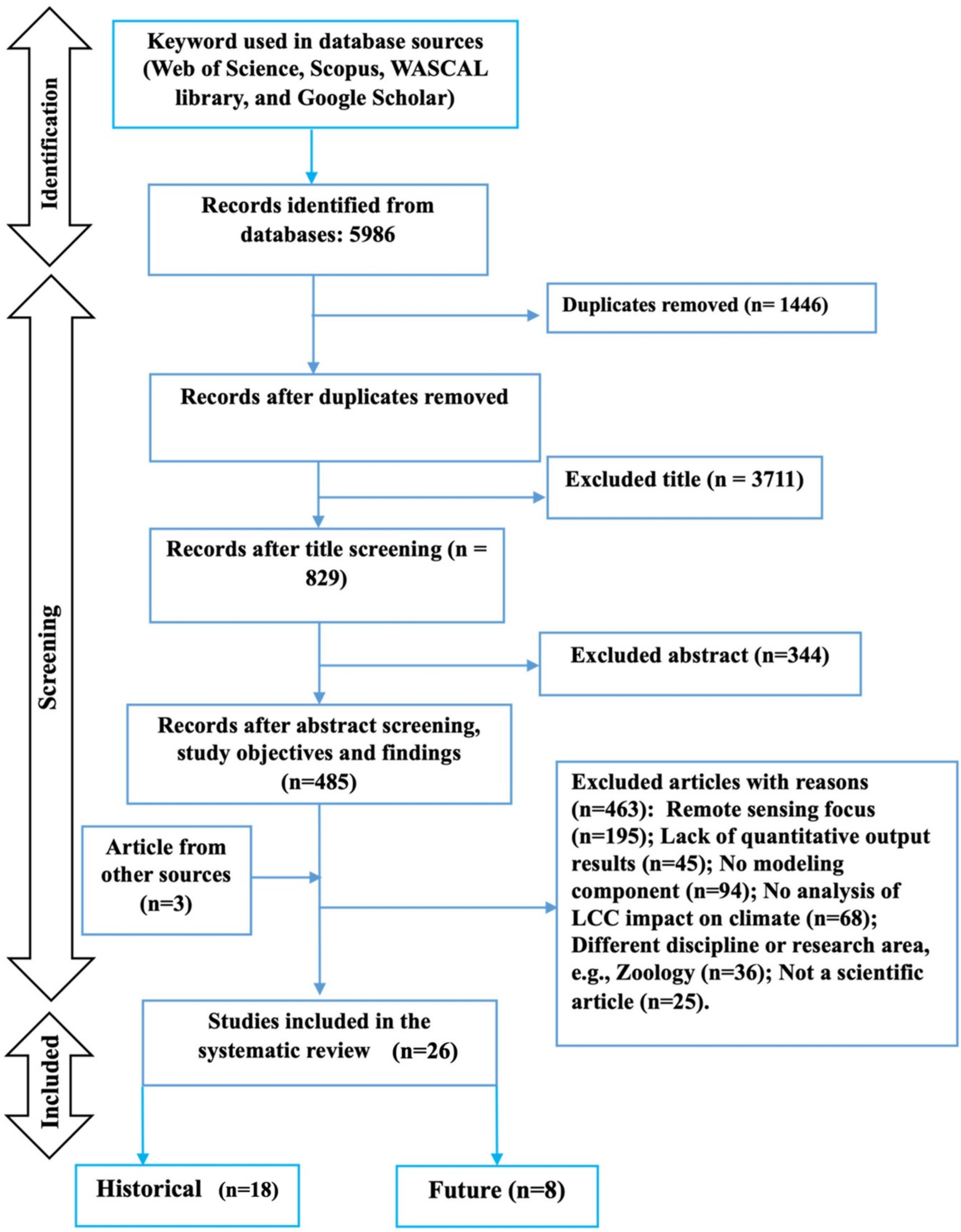

Figure 1. Flowchart illustrating the number of articles at each PRISMA manual screening process stage. In the diagram, '*n*' represents the number of articles. At the final stage, selected articles were classified by model simulation periods rather than publication year, with the number of studies focused on historical ($n = 17$) and future ($n = 8$) climate conditions.

Idrissou *et al* 2022, Achugbu *et al* 2023, Crook *et al* 2023, Mortey *et al* 2023); (ii) afforestation scenarios (referred to as 'Afforestation'), where grassland and/or cropland areas are partially or fully replaced by forest (see Abiodun *et al* 2012a, Sylla *et al* 2015, Diba *et al* 2016, Diasso and Abiodun 2017, Noulèkoun *et al* 2018, Odoulami *et al* 2018, Achugbu *et al* 2021, Smiatek and Kunstmann 2023), as detailed in table 1.

In terms of seasonal variation, most studies conducted in West Africa have predominantly focused on the West African Monsoon (WAM) season, with limited attention given to other seasons (see table 1). However, there is a notable lack of standardized definitions of seasonal periods across studies (see table 1). For example, the WAM season has been variably defined as June–July–August (JJA), June–July–August–September (JJAS),

Table 1. Summary of the characteristics of the papers included in this study. ΔT, ΔP, ΔAlbedo, and ΔLAI represent changes in surface air temperature, precipitation, surface albedo, and leaf area index, respectively, in response to different LCC scenarios. The selected studies are systematically categorized based on key model parameterization configurations: (i) models with dynamic vegetation representation versus those without, (ii) models employing parameterized convection schemes versus convection-permitting approaches, and (iii) models using idealized versus realistic LCC scenarios.

Papers	Variables	Impact scale	Climate models	Vegetation models	Simulation periods and scenarios	Seasonal/annual	Dynamic Vegetation	Parametrized convection (PC) or convection-permitting (CP)	Idealized (ID) or realistic (RE)	LCC scenarios: Deforestation (DEF), Afforestation (AFF)
Glotfelty *et al* (2021)	ΔT, ΔP, ΔAlb	West Africa	WRF	Noah, Noah-MP, CLM-D, CLM-AF	2010–2015	Annual	No	PC	RE	DEF, AFF
Abiodun *et al* (2008)	ΔT, ΔP, ΔAlb	West Africa	RegCM3	BATS	1981–1990	Annual	No	PC	ID	DEF
Wang *et al* (2015)	ΔT, ΔP, ΔAlb, ΔLAI	West Africa	RegCM4.1, UCLA, CAM5	CLM4	2001–2006	AM, JJAS	No	PC	ID	DEF
Achugbu *et al* (2021)	ΔT, ΔP	West Africa	WRF3.9.1.1	Noah-MP	2012	Annual	No	PC	ID	DEF, AFF
Boone *et al* (2016)	ΔT, ΔP, ΔAlb, ΔLAI	West Africa	UCLA-AGCM, UCLA-GFS, UCONN CAM5, GSFC GOES-5, UKMO HadGEM 2-A	SSIB-1, CLM 3.5, CLSM, MOSES	1952–1957	JAS	No	PC	ID	DEF
Achugbu *et al* (2023)	ΔT, ΔP, ΔAlb	West Africa	WRF3.9.1.1	Noah-MP	2011–2012	DJF, JAS	No	PC	ID	DEF

(Continued.)

Table 1. (Continued.)

Papers	Variables	Impact scale	Climate models	Vegetation models	Simulation periods and scenarios	Seasonal/annual	Dynamic Vegetation	Parametrized convection (PC) or convection-permitting (CP)	Idealized (ID) or realistic (RE)	LCC scenarios: Deforestation (DEF), Afforestation (AFF)
Sy *et al* (2017)	ΔT, ΔP, ΔAlb, ΔLAI	West Africa	ARPEGE, CCAM, CCSM, ECEARTH-, ECHAM5, IPSL, SPEEDY	ISBA, CABLE, CLM, TESSEL, JSBACH, ORCHIDEE, LPJmL	1970–1999	Annual	No	PC	RE	DEF
Abiodun *et al* (2012a)	ΔT, ΔP, ΔAlb	West Africa	RegCM3	BATS	2030–2050 based on A1B scenario	MAM, JJA	No	PC	ID	AFF
Odoulami *et al* (2018)	ΔP, ΔAlb	West Africa	RegCM 4.3 and WRF	BATS and Noah LSM	2031–2060 under RCP4.5 scenario	Annual	No	PC	ID	AFF
(Abiodun *et al* (2012b)	ΔT, ΔP	Nigeria	RegCM3	BATS	2031–2050 under A1B scenario	MJJ, JAS	No	PC	ID	AFF
Zheng and Eltahir (1997)	ΔT, ΔP	West Africa	Zonally-symmetric model		1950–1969	Annual	No	PC	ID	DEF
Diasso and Abiodun (2017)	ΔT, ΔP	West Africa	RegCM4 and WRF3.5.1	BATS1E and MPI-ESM-LR	2031–2060 under RCP4.5 scenario	JAS	No	PC	ID	AFF
Diba *et al* (2018)	ΔT, ΔP	West Africa	RegCM4.5	BATS1E	1990–2009	JJAS	No	PC	ID	AFF
Oguntunde *et al* (2012)	ΔT, ΔP	West Africa	RegCM3	BATS	2031–2050 under A1B scenario	JFM, AMJ, JAS, OND	No	PC	ID	AFF
Diba *et al* (2016)	ΔT, ΔP	West Africa	RegCM4	BATS1E	2003–2009	JJAS	No	PC	ID	AFF

(Continued.)

Table 1. (Continued.)

Papers	Variables	Impact scale	Climate models	Vegetation models	Simulation periods and scenarios	Seasonal/annual	Dynamic Vegetation	Parametrized convection (PC) or convection-permitting (CP)	Idealized (ID) or realistic (RE)	LCC scenarios: Deforestation (DEF), Afforestation (AFF)
Ji *et al* (2015)	ΔT, ΔP	West Africa	RegCM4.3.4	CLM4.5	2081–2099 Under RCP8.5 scenario	Annual	No	PC	ID	DEF
Bamba *et al* (2019)	ΔT, ΔP	West Africa	RegCM4.7	BATS	2000–2011	JJAS	No	PC	ID	AFF
Charney (1975)	ΔP, ΔAlb	West Africa	Hadley circulation		1973	JA	No	PC	ID	DEF
Sylla *et al* (2015)	ΔT, ΔP	West Africa	RegCM4.3	CLM3.5	1998–2010	DJF, JJA	No	PC	RE	DEF
Chilukoti and Xue (2020)	ΔT, ΔP, ΔAlb, ΔLAI	West Africa	GFS	SSiB2	1948–2010	JJA, DJF	No	PC	RE	DEF
Mortey *et al* (2023)	ΔT, ΔP	West Africa	GLEAM	ESA CCI LC	1992–2019	Annual	No	PC	RE	DEF
Sy and Quesada (2020)	ΔT, ΔP	West Africa	CanESM2, HadGEM2-ES, IPSL-CM5A-LR, MPI-ESM-LR, MIROC-ESM	CTEM, JULES, ORCHIDEE, SEIB-DGVM, JSBACH	2071–2100 under RCP8.5 and RCP2.6 scenarios	Annual	Yes/No	PC	RE	DEF
(Smiatek and Kunstmann (2023)	ΔT, ΔP	West Africa	MPAS7	Noah LSM	1997–2012	JJAS	No	PC	ID	AFF
Crook *et al* (2023)	ΔT, ΔP, ΔAlb	West Africa	MetUM	JULES	2014	June	No	CP	RE	DEF
Duku and Hein (2021)	ΔP	West Africa		ConvLSTM	2000–2012	JJA	No	PC	ID	DEF
Saley *et al* (2019)	ΔT	West Africa	RegCM4	BAST	1988–2012	JJA	No	PC	ID	AFF

or July–August–September (JAS) (see table 1). These discrepancies in seasonal delineation can lead to variations in the estimated magnitude of LCC-induced climate signals. In other words, such inconsistencies may affect the accuracy and comparability of findings related to the seasonal biophysical effects of LCC and may contribute to divergent reports of temperature and precipitation responses.

In table 1, modeling studies have been systematically categorized based on different explicit parameterization configurations. The classification was structured according to the following key criteria: (i) dynamic vegetation representation, distinguishing models that incorporate dynamic vegetation processes from those that do not; (ii) convection schemes, contrasting models that use parameterized convection (PC) schemes with those that use convection-permitting (CP) approaches; and (iii) LCC scenarios, grouping studies based on whether they used idealized (e.g. where the total or partial fractions of the forest cover are removed or replaced with another land-cover category) or 'realistic' LCC scenarios. This categorization provides a clear framework for comparing methodological approaches and their implications in the modeling studies.

Furthermore, among the 26 selected papers, most studies conducted in West Africa do not include vegetation as a dynamic component (table 1). Instead, the seasonal evolution of the LAI is generally prescribed using remote sensing products, with monthly LAI values typically held constant across years (Boone *et al* 2016, Sy *et al* 2017, Glotfelty *et al* 2021). Notably, only one study (see, Sy and Quesada 2020) included models with dynamic vegetation capabilities (table 2), showing that the deforestation signal is generally more pronounced when dynamic vegetation processes are enabled. This limited representation is largely due to the relatively recent development of dynamic vegetation models, which are more commonly integrated into GCMs (Quillet *et al* 2010, Sy and Quesada 2020). Dynamic vegetation models improve the representation of land–atmosphere interactions by allowing vegetation to respond dynamically to climatic changes, thereby improving the accuracy of LCC impact estimates (Westermann *et al* 2024).

Regarding convection schemes, table 1 shows that most studies used PC schemes, with only one study using a CP approach (see, Crook *et al* 2023) to assess deforestation impacts. Regarding the LCC scenarios, most studies were based on idealized scenarios, typically involving more drastic deforestation or afforestation, while six of the 26 studies used 'realistic' scenarios (table 1). Concerning the future scenarios, among the seven studies focusing on projected climate changes, three considered the A1B scenario from the Fourth Assessment Report (AR4) (Abiodun *et al* 2012a, 2012b, Oguntunde *et al* 2012), while four studies employed Representative Concentration Pathways (one study used RCP2.6, two used RCP4.5, and one used RCP8.5) to assess the effects of future LCC (Ji *et al* 2015, Diasso and Abiodun 2017, Odoulami *et al* 2018, Sy and Quesada 2020), although with different simulation periods.

3. Review results and discussion

3.1. Model-based LCC studies in West Africa

Among the 26 papers considered, the majority were published after 2017, with the earliest study identified being Charney (1975) (see table 1 and figure S2). Approximately 60% of these publications were published in the last six years, indicating a growing focus on LCC's regional and local biophysical impacts in West Africa. Several factors likely contribute to this increased interest: (i) West Africa is particularly vulnerable to climate impacts due to its high exposure and limited adaptive capacity (Barros *et al* 2014), and has experienced significant multidecadal rainfall variability and severe droughts, particularly in the 1970s and 1980s (Nicholson 2013, Masih *et al* 2014). Additionally, since the mid-1970s, mean annual and seasonal temperatures have increased by 1 °C–3 °C, with the largest increases observed in the Sahara and Sahel regions (Cook and Vizy 2015, Lelieveld *et al* 2016, Trisos *et al* 2022); (ii) the region also faces critical land-use challenges, such as deforestation, overgrazing, and land degradation due to agricultural expansion and urbanization, which have significantly altered the landscape (Boone *et al* 2016, Sy *et al* 2017, Bliefernicht *et al* 2018, Potapov *et al* 2022). These changes strongly influence land–atmosphere interactions, intensifying climate extremes and altering local and regional climate systems (Russo *et al* 2016, Barry *et al* 2018, Sy and Quesada 2020); (iii) since Charney's (1975) seminal work on the link between desertification and drought in the Sahel, West Africa has been at the center of discussions on the biophysical impacts of deforestation and desertification (Zheng and Eltahir 1997, Fuller and Ottke 2002); (iv) the population of the region has almost doubled in the last 50 years and is expected to double again by mid-century, leading to increasing pressure on land resources and accelerating land-use change (Van Bavel 2013, Sy *et al* 2017).

3.2. Simulated temperature responses

Surface air temperature responses to LCC scenarios of afforestation and deforestation over the simulation periods are summarized in figure 2(a) and table 2. Boxplots display the temperature responses from individual models (represented by different cross symbols), while the triangle represents the multi-model ensemble mean (i.e. the average result from all models). On average, deforestation scenarios lead to regional warming, with simulated values of $+0.26 \pm 0.12$ °C during the historical period and $+0.88 \pm 0.25$ °C in future scenarios (95% confidence interval). In contrast, afforestation produces a cooling

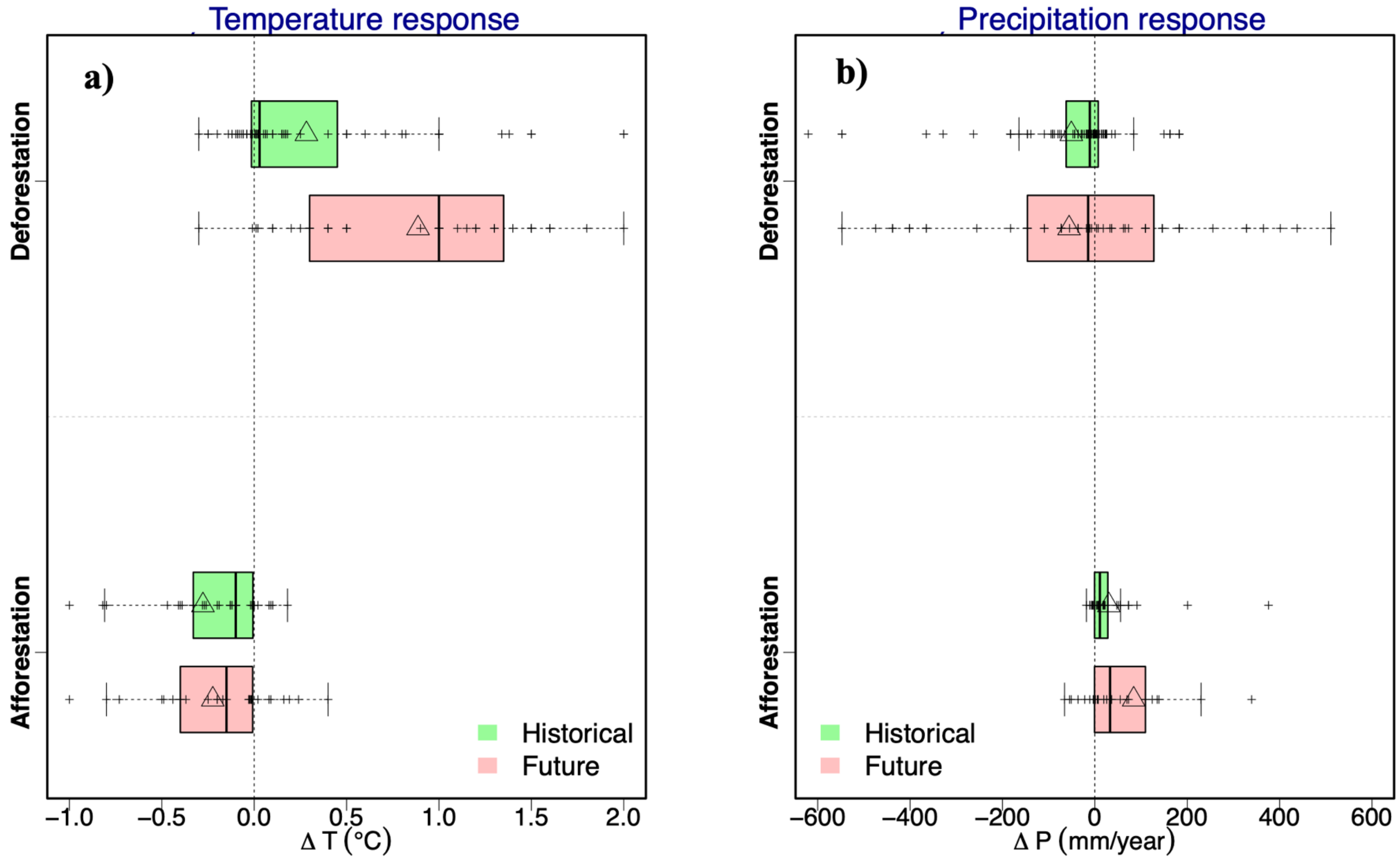

Figure 2. Biophysical effects of LCC (deforestation and afforestation scenarios) on surface air temperature (°C) (a) and precipitation (mm yr^{-1}) (b). The boxplots show the distribution of individual model temperature and precipitation responses to LCC scenarios. The triangle indicates the multi-model ensemble mean (i.e. the average of results from different individual model), while each cross represents the response of a single model. The median of the multi-model ensemble is marked with a black line; the lower hinge of each box represents the first quartile (Q1, 25th percentile), and the upper hinge represents the third quartile (Q3). The bars indicate the maximum and minimum values, with individual model responses beyond the whiskers plotted as black circles. Green and red boxplots represent model responses over different simulation periods (historical and future).

Table 2. Regional averages of surface air temperature (°C) and precipitation (mm yr^{-1}) responses under different land cover change (LCC) scenarios based on model outputs. The table shows the regional average, 95% Confidence Interval (95% CI), and maximum and minimum responses calculated from different individual model simulations. The regional mean significance at the 0.05 level was calculated using the rank-based non-parametric Mann–Whitney–Wilcoxon (MWW) test.

			Temperature response (°C)				
Period	LCC scenarios	Mean	(95% CI)	*p*-value	Max	Min	Entries
Historical	Deforestation	0.26	0.12	<0.05	2	–0.3	14[1,3–7,11,18,19,20,23,25]
	Afforestation	–0.24	0.14	<0.05	0.18	–3	6[1,4,13,14,16,22]
Future	Deforestation	0.88	0.25	<0.05	3.4	–0.3	4[2,15,21]
	Afforestation	–0.22	0.14	<0.05	0.4	–1.48	3[8,10,12]
			Precipitation response (mm d^{-1})				
Historical	Deforestation	–0.13	0.08	<0.05	0.5	–2.5	16[1,3–7,11,17–20,23,24]
	Afforestation	0.10	0.18	<0.05	4.1	–0.05	6[1,4,13,14,16,22]
Future	Deforestation	–0.15	0.28	>0.05	2.1	–5	4[2,15,21]
	Afforestation	0.22	0.16	<0.05	1.8	–0.18	4 [8,9,10,12]

[1]Glotfelty *et al* (2021); [2]Abiodun (*et al* 2008); [3]Wang *et al* (2015); [4]Achugbu *et al* (2021); [5]Boone *et al* (2016); [6]Achugbu *et al* (2023); [7]Sy *et al* (2017); [8]Oguntunde *et al* (2012); [9]Odoulami *et al* (2018); [10]Abiodun *et al* (2012a); [11] Zheng and Eltahir (1997); [12]Diasso and Abiodun (2017), [13](Diba *et al* (2018); [14]Diba *et al* (2016); [15]Ji *et al* (2015); [16]Bamba *et al* (2019); [17]Charney (1975); [18]Sylla *et al* (2015); [19]Chilukoti and Xue (2020); [20]Mortey *et al* (2023); [21] Sy and Quesada (2020); [22]Smiatek and Kunstmann (2023); [23]Crook *et al* (2023); [24]Duku and Hein (2021), [25]Saley *et al* (2019).

effect, with values of -0.24 ± 0.14 °C in the historical period and -0.22 ± 0.14 °C in future projections (see table 2 and figure 2(a)). As expected, the warming due to deforestation is more pronounced in the future, although the range of temperature change is large and could include negative values (–0.3 °C to +2.0 °C). For afforestation, the largest cooling effect occurs during the historical period, with temperature changes ranging from −0.2 °C to +1.0 °C. This suggests that afforestation had a more significant cooling impact historically, likely due to greater vegetation cover. By contrast, in future scenarios, elevated levels of atmospheric CO_2 and altered radiation balances may diminish the cooling effects of afforestation.

Regarding the emission scenarios, on average, projections of temperature changes under the RCP8.5 scenario are more pronounced than under RCP2.6 (see table 3), mainly because tropical deforestation is projected to be more extensive under RCP8.5 than under RCP2.6 (Ward *et al* 2014). In other words, under the RCP2.6 scenario, the impact of deforestation on regional climate is weaker and statistically less significant compared to RCP8.5 (see table 3). This can be attributed to the lower greenhouse gas (GHG) concentrations and reduced radiative forcing associated with RCP2.6, which result in a more stabilized climate system with diminished model sensitivity to deforestation (Sy and Quesada 2020). Concerning afforestation, our findings indicate that the climate signal—particularly under the RCP4.5 scenario—is approximately twice as pronounced as that observed under the A1B scenario for temperature changes (see table 3). This stronger climate response under RCP4.5 compared to A1B can be attributed to several key factors: (i) the differences in radiative forcing and emission pathways between the two scenarios. The A1B scenario (Nakicenovic and Swart 2000) assumes a balanced energy mix with moderate GHG emissions, representing a future world characterized by rapid economic and low population growth. In addition, under A1B, radiative forcing is projected to reach approximately 6.0 W m^{-2} by 2100. In contrast, RCP4.5 is a stabilization scenario in which emissions peak around mid-century and then decline, leading to a lower radiative forcing of 4.5 W m^{-2} by 2100 (Thomson *et al* 2011). While RCP4.5 has lower overall radiative forcing than A1B, the climate system remains sensitive enough for afforestation to induce distinct biophysical effects, including alterations in surface energy balance and regional precipitation patterns; (ii) unlike A1B, RCP scenarios explicitly integrate land-use change assumptions, including afforestation, as part of climate mitigation strategies (Thomson *et al* 2011). In other words, RCP4.5 incorporates larger afforestation efforts compared to A1B, leading to stronger land-cover-induced climate feedback. In contrast, A1B does not explicitly prioritize afforestation, meaning its land-use effects are less emphasized in climate models (Falloon *et al* 2012). In summary, the explicit inclusion of afforestation as a mitigation strategy in RCP4.5, combined with its goal of stabilizing radiative forcing at a lower level, may enhance the afforestation's climate impacts compared to A1B. It is worth noting that the difference in the simulation and model configurations may influence the model responses; for instance, the models used in RCP scenarios tend to incorporate updated land surface schemes, which may enhance the representation of afforestation effects compared to the older A1B-based simulations (Monerie *et al* 2012).

Table 3. Annual and seasonal changes in temperature and precipitation under different model parameterization configurations. The table compares the effects of convection schemes, land cover change scenarios (both idealized vs realistic), and future emission scenarios on climate responses.

Variables	Future scenarios				Seasonal changes					Idealized (ID) or realistic (RE) scenarios		Parametrized convection (PC)/convection-permitting (CP)	
	A1B	RCP2.6	RCP4.5	RCP8.5	Annual	MAM	DJF	JJA	SON	ID	RE	PC	CP
Afforestation													
*T*mean (°C)	**–0.33** [8,10,14]	NA	**–0.6** [12]	NA	**–0.13** [1,4,9]	**–0.28**[8,14]	**–0.15**[14]	**–0.27** [8,10, 12–15, 17,23, 26]	**–0.4**[14]	**–0.28** [4,8,10, 12–15, 17,23,26]	**–0.2** [1]	**–0.28** [1,4,8, 10, 12–15, 17,23,26]	NA
*P*mean (mm d^{-1})	**0.41** [8,10,14]	NA	**1.24** [9,12]	NA	**0.07** [1,4,9]	**0.10** [8,14]	**3** [14]	**1.04**[8,10, 12–15, 17, 23, 26]	NA	**0.72**[4,8,9,10, 12–14, 17,23]	**0.02**[1]	**0.55** [1,4,8, 9,10, 12–15, 17,23]	NA
Deforestation													
*T*mean (°C)	NA	**0.02**[22]	NA	**0.76**[16,22]	**0.27** [1,2,4, 7,11,16,21,22]	**0.01** [3, 22]	**0.12**[6, 19,22]	**0.38**[3,5,6,19,20,22,24]	**0.1**[22]	**0.31** [2,4,6,11,14,16]	**0.25** [1,3,5,7,19,20,21,22,24]	**0.29** [1–7,11, 16,19,20, 21,22,24]	**0.0**[24]
*P*mean (mm d^{-1})	NA	**–0.01**[22]	NA	**–0.02**[16, 22]	**–0.08** [1,2,4,11,16,21,22]	**–0.40**[3,22]	**–0.1**[6, 19,22]	**–0.43** [3,5,6,7,19,20,22,24,25]	**–0.01**[22]	**–0.43** [2,3,4,5,6,11,16, 18,25]	**–0.03** [1,7,19,20,21,22,24]	**–0.15** [1–7, 11,16,18,19,20,21,22, 24,25]	**+0.64**[24]

[1]Glotfelty *et al* (2021); [2]Abiodun *et al* (2008); [3]Wang *et al* (2015); [4]Achugbu *et al* (2021); [5]Boone *et al* (2016); [6]Achugbu *et al* (2023); [7]Sy *et al* (2017); [8]Abiodun *et al* (2012a); [9]Odoulami *et al* (2018); [10]Abiodun *et al* (2012b); [11]Zheng and Eltahir (1997); [12]Diasso and Abiodun (2017); [13]Diba *et al* (2018); [14]Oguntunde *et al* (2012), [15]Diba *et al* (2016); [16]Ji *et al* (2015); [17]Bamba *et al* (2019); [18]Charney (1975); [19]Sylla *et al* (2015); [20]Chilukoti and Xue (2020); [21]Mortey *et al* (2023); [22]Sy and Quesada (2020); [23]Smiatek and Kunstmann (2023); [24]Crook *et al* (2023); [25]Duku and Hein (2021); [26]Saley *et al* (2019); NA means the study did not examine the variable.

At the seasonal scale, for deforestation, the most pronounced warming is observed during the WAM season (JJA), with average temperature increases of up to 0.38 °C (see table 3). This warming is also consistent during the year-round, likely due to a reduction in evapotranspiration. Wang *et al* (2015) show that, in the context of regional climate responses to deforestation in West Africa, changes driven by evapotranspiration play a more important role than changes in albedo during the monsoon season. Specifically, decreases in evapotranspiration dominate over increases in albedo, resulting in net warming across the Sahel (Boone *et al* 2016, Chilukoti and Xue 2020, Sy and Quesada 2020, Achugbu *et al* 2023). Abiodun *et al* (2008) further illustrate that deforestation can induce a warming effect of 0.1 °C–0.5 °C over the northern Sahel while reducing temperatures by 0.15 °C–0.5 °C in southern West Africa during spring and summer. Similarly, Chilukoti and Xue (2020) found a comparable warming effect over degraded areas in West Africa, with deforestation causing a significant surface warming of 0.82 K during the summer season (JJA). Finally, in their analysis of the diurnal cycle of deforestation effects in June, Crook *et al* (2019) found warmer near-surface temperatures during the day (up to 1 K) and cooler near-surface temperatures at night (about −0.5 K) in deforested areas, resulting in a net warming effect over the entire day.

For afforestation, the cooling effect is most pronounced during the post-monsoon autumn season (SON), with temperatures decreasing by up to −0.4 °C on average (Oguntunde *et al* 2012, Sy *et al* 2024). This cooling is also consistent throughout all seasons and is likely to be driven primarily by increased forest transpiration as a result of increased leaf density. In contrast, during the monsoon season (JJAS), the cooling effect is less pronounced, with temperature reductions reaching up to −0.27 °C on average (see table 3). However, during the pre-monsoon season (MAM), Ingrosso and Pausata (2024) identified a net warming effect associated with afforestation. This warming is mainly driven by a reduction in surface albedo, which leads to increased absorption of solar radiation. The concurrent increases in evapotranspiration and cloud cover during this period are too weak to effectively compensate for the albedo-induced radiative forcing, resulting in a net temperature rise.

Regarding the potential impact of LCC scenarios, table 3 shows that simulations using idealized deforestation scenarios have more pronounced climate impacts than those based on 'realistic' scenarios. Specifically, idealized deforestation scenarios lead to a temperature increase of about 0.31 °C, while realistic scenarios show a smaller increase of about 0.25 °C. Similarly, idealized scenarios show a cooling effect of −0.28 °C for afforestation, while realistic scenarios show a more moderate cooling of −0.2 °C. These differences are probably because idealized scenarios typically prescribe more drastic and uniform LCCs, such as replacing existing vegetation with a single forest type or vice-versa, which amplifies the simulated climate impacts. In contrast, realistic scenarios incorporate more nuanced and gradual changes in land cover, which better reflect real-world conditions and result in less temperature responses. This highlights the importance of scenario design in accurately assessing the climate impacts of LCC, as idealized scenarios may overestimate the magnitude of changes compared to more realistic representations.

3.3. Simulated precipitation responses

Figure 2(b) shows the responses of precipitation (mm yr^{-1}) to deforestation and afforestation scenarios, comparable to the temperature patterns observed in figure 2(a). Deforestation consistently led to regional decreases in precipitation in both the historical and future periods. Specifically, historical deforestation reduced precipitation by -0.13 ± 0.08 mm d^{-1} (-47 ± 29 mm yr^{-1}), while future projections show a slightly larger reduction of -0.15 ± 0.28 mm d^{-1} (-54 ± 102 mm yr^{-1}) (see table 2 and figure 2(b)). Conversely, afforestation led to regional increases in precipitation of $+0.10 \pm 0.18$ mm d^{-1} ($+40 \pm 67$ mm yr^{-1}) in the historical period and 0.22 ± 0.16 mm d^{-1} (80 ± 58 mm yr^{-1}) in the future scenarios. As expected, both deforestation and afforestation impacts increased in the future projections, but with considerable variability between model results. Deforestation projections included potential wetting effects, albeit with a large range in precipitation changes from −450 to +500 mm yr^{-1}, while afforestation results included potential drying effects, again with a large model response's spread from −75 to +250 mm yr^{-1} (figure 2(b)).

Regarding deforestation, as also observed with temperature, projections of precipitation changes under the RCP8.5 scenario are approximately twice as pronounced as those under RCP2.6 (see table 3). This is primarily because tropical deforestation is projected to be more extensive under RCP8.5 compared to RCP2.6 (Ward *et al* 2014). In contrast, for afforestation, the climate signal—particularly under the RCP4.5 scenario—is, on average, about three times more pronounced than that observed under the A1B scenario for precipitation changes (see table 3). This difference is likely driven by several key mechanisms, as previously discussed, including (i) the differences in radiative forcing and emission pathways between the two scenarios and (ii) the explicit integration of land-use changes assumptions, such as afforestation, as part of climate mitigation strategies in RCP4.5. These factors collectively contribute to the stronger climate signal observed under RCP4.5 compared to A1B.

At the seasonal scale, the most pronounced effect of deforestation is also observed during the WAM season in JJAS, leading to a significant reduction in precipitation, with an average decrease of up to −0.43 mm d^{-1} (see table 3). These results are consistent with studies showing that both historical and future deforestation over West Africa can lead to simulated decreases in precipitation (Ji *et al* 2015, Wang *et al* 2015, Boone *et al* 2016, Sy *et al* 2017, Sy and Quesada 2020). The reduction in rainfall is observed throughout the year, with a significant decrease also simulated during the pre-monsoon season (MAM), with an average decrease of up to −0.4 mm d^{-1}. Wang *et al* (2015) found that the decline in precipitation during the pre-monsoon season is spatially coherent across West Africa, with more pronounced declines near the coast, where the magnitude of the decline can exceed 2 mm d^{-1} in certain areas. During the WAM season, the strongest reduction in precipitation is centered around 12°N, where deforestation causes a weakening of the monsoon circulation (Wang *et al* 2015). This leads to a southward shift of the rain belt, creating a dipole pattern in the precipitation response during JJAS. Specifically, rainfall decreases over the Sahel region while increasing over the Guinea Coast. The mechanisms through which deforestation may lead to increased rainfall in certain areas can be attributed to several factors. For instance, tropical grasslands in the tropics are sometimes erroneously parameterized as more evaporative in climate models, leading to an overestimation of precipitation when the forest is replaced by grassland. Additionally, when deforestation occurs on a smaller scale, a phenomenon known as the 'vegetation breeze' can occur (Cochrane and Laurance 2008, Garcia-Carreras and Parker 2011). This process involves the creation of a low-pressure zone over the deforested area, which draws in locally heated, moist air masses from surrounding vegetated regions. As these air masses ascend, cloud formation and precipitation over the deforested area is enhanced. Although based on 5 d simulations, under the CP model, Crook *et al* (2023) also observed enhanced rainfall over deforested areas in West Africa. They reported an average increase of 6% (0.64 mm d^{-1}) in rainfall over deforested pixels throughout the day, primarily driven by more frequent and larger storms, with a lesser contribution from more intense storms between 18:00 and 06:00 UTC, with rainfall changes being more pronounced during the night than during the day. Furthermore, the magnitude and spatial distribution of these rainfall changes are strongly influenced by soil moisture conditions and the proximity of deforestation to the coast due to interactions with sea breeze dynamics.

For afforestation, most studies simulate a significant increase in precipitation during the rainy season, with an average increase of 1.04 mm d^{-1} (see table 3). However, Oguntunde *et al* (2012) reported a higher increase during the winter season, with changes of up to 3.0 mm d^{-1} observed in the Niger Delta in a future afforestation experiment involving the conversion of grassland to tropical forest. The increase in rainfall following afforestation is consistent throughout the year and is mainly driven by increased transpiration and the release of recycled moisture through forest evapotranspiration (Abiodun *et al* 2012a, Oguntunde *et al* 2012, Sy *et al* 2017, Ingrosso and Pausata 2024). These processes may also contribute to the northward extension of the monsoon (Pausata *et al* 2020, Ingrosso and Pausata 2024). Such effects are particularly pronounced during the rainy season when water availability is at its peak, and hydrological changes can significantly influence precipitation patterns and processes (Malhi *et al* 2008, Phillips *et al* 2009, Kumagai and Porporato 2012), thereby modulating atmospheric feedback mechanisms (Meir *et al* 2006, Bonan 2008).

Similar to temperature, idealized scenarios for both deforestation and afforestation show stronger climate impacts on precipitation than those based on realistic LCC scenarios (table 3). On average, idealized deforestation scenarios lead to a larger decrease in precipitation, with an estimated decrease of about −0.43 mm d^{-1}, while realistic deforestation scenarios show a much smaller decrease of about −0.03 mm d^{-1}. Similarly, afforestation in idealized scenarios produces a significant wetting effect, with increases in precipitation of up to 0.72 mm d^{-1}. In contrast, realistic afforestation scenarios show only a marginal effect, with an increase of about 0.02 mm d^{-1}, on average, with a high effect, particularly for afforestation in experiments where the savanna is converted to a woody savanna (Glotfelty *et al* 2021). These discrepancies are likely due to the more abrupt and extensive LCCs in idealized scenarios compared to realistic scenarios, which incorporate gradual and spatially heterogeneous changes that better represent real-world conditions.

3.4. Comparison with other tropical studies

According to the Special Report on Climate Change and Land (IPCC-SRCCL 2019), there is *a high confidence* that large-scale tropical deforested areas are warmer than surrounding non-deforested zones. After a pantropical deforestation experiment, a significant mean biophysical warming of +0.61 ± 0.48 °C is found when averaged over the entire tropics ($n = 18$ simulations across 15 studies). Perugini *et al* (2017), integrating more tropical subregional studies, found a very similar significant biophysical warming of 0.60 ± 0.26 °C over the tropical zones ($n = 34$ simulations across 12 studies). In West Africa, our quantitative review indicates a smaller warming response of +0.26 ± 0.12 °C, likely due to the relatively small extent of deforestation simulated in this region, as discussed by Sy *et al* (2017). However, projected future deforestation shows a much larger warming response of +0.88 ± 0.25 °C, probably due to more drastic LCCs and more sensitive models. We found that the evapotranspiration reduction is the leading driver (see figure S3), largely outdoing the albedo-cooling effect in response to tropical deforestation, as commonly reported in the literature both for models and observation-based outputs (Perugini *et al* 2017, Jia *et al* 2019).

Moreover, large-scale tropical deforestation results in a significant mean rainfall decrease, as confirmed by the overwhelming majority of studies, both observational and modeling results (Lawrence and Vandecar 2015, Perugini *et al* 2017, Spracklen *et al* 2018, Sy and Quesada 2020). This is consistent with our West African study: West African deforestation results in a rainfall decrease on average (table 2 and figure 2(b)). Perugini *et al* (2017) reported a mean simulated decrease of −288 ± 110 mm yr^{-1} (95% confidence interval) for tropical studies ($n = 42$ simulations), while our results indicate a −47 to −55 mm yr^{-1}, a much lower number than most tropical modeling studies. Furthermore, based on observational satellite-based methodology, local reductions in precipitation ranged from −115 ± 86 mm yr^{-1} in South East Asia to −55 ± 28 mm yr^{-1} in the Amazon and −50 ± 45 mm yr^{-1} in the Congo for a comparable 20% historical deforestation (Smith *et al* 2023). This last value in Africa is coherent with the modeling studies found in West Africa (figure 2(c)). Given a 2200 mm yr^{-1} annual mean rainfall over the Amazon basin, across all simulations ($n = 96$), the average change in annual mean Amazon basin rainfall induced by historical deforestation was −264 ± 242 mm yr^{-1} (Spracklen and Garcia-Carreras 2015), a much higher estimate than the observational-based estimates. However, it is worth noting that observation-based estimates account for fewer deforestation impacts than model-based ones: the space-for-time assumption does not consider remote impacts of deforested pixels, trends in global climate change partly induced by LCCs, or slight hydroclimatic dynamic differences between neighboring pixels (though the assumption of a common background climate is made for distance) (Quesada *et al* 2017, Chen and Dirmeyer 2020, Sy and Quesada 2020).

Although the Sahel has shown signs of recovery from the severe droughts of the 1970s and 1980s, rainfall levels have not fully returned to pre-drought conditions (Sylla *et al* 2016a, Biasutti 2019, Nouaceur and Murarescu 2020). While multiple datasets confirm this trend, there remains variability in magnitude due to observational limitations in West Africa (e.g. Sanogo *et al* 2015, Nicholson *et al* 2018). Recently, Tano *et al* (2023) reported a decrease in precipitation in most West African countries, with the most significant decrease observed in Liberia. Part of this decreasing trend has been forced by global warming through a reduction of the land-sea thermal gradient, which in turn led to a weakened monsoon circulation and a northward shift of monsoon rainfall, inducing less rainfall in West Africa (Tano *et al* 2023). Another large driver of this trend is tropical West African deforestation (Quesada *et al* 2017, Sy *et al* 2017), which reduced the evapotranspiration flux with shallower vegetation but also the available energy for thermal fluxes in general in response to a higher albedo. Indeed, to highlight the potential importance of this driver in this region of the globe, Quesada *et al* (2017), using 5 global coupled models with and without future plausible LCC scenarios found that deforestation decreases by 41% future WAM boost simulated under future climate change because of a decrease in evapotranspiration, cloud amount along with more anticyclonic conditions. However, due to the lack of other attribution studies in the region with the best regional and GCMs available associated with plausible LCC scenarios in West Africa, we still lack key information on the relative contribution of both drivers on climate. Under future global warming scenarios, precipitation changes in West Africa are not consensual and are non-significant for the multi-model means, as simulated by the climate models (Hartley *et al* 2015, Almazroui *et al* 2020). For all those reasons, given the temperature and precipitation responses to LCC, we infer a lower land–atmosphere interaction tropical hotspot in West Africa simulated by the models.

3.5. Planting trees as key helpers to help mitigate regional warming and drying

Simulation results due to large-scale afforestation, albeit few (less or equal to 6 outputs per scenario, see figures 2(b) and (c)), indicate substantial and significant cooling and wetting. The biophysical cooling found of approx. −0.2 °C in response to large-scale afforestation can moderately mitigate the regional West African warming of 0.2 °C per decade approximately (1970–2014, Iyakaremye *et al* 2021a), without even accounting for the biogeochemical effect (Bonan 2008). Moreover, our results indicate that the regional rainfall increase by 40–80 mm yr^{-1} in response to large-scale reforestation or afforestation may compensate for the rainfall amount loss from significant recent drying trends in countries of West Africa like Guinea, Liberia, Ghana, or Ivory (Tano *et al* 2023).

Afforestation also presents significant socio-economic and environmental implications, necessitating careful consideration for sustainable development and policy implementation. While it can improve local microclimates by increasing humidity and reducing temperatures, thereby benefiting rain-fed agriculture in some regions (Waongo *et al* 2024), it may also compete with agricultural land, threatening food security, particularly in semi-arid areas where farming is a primary livelihood (Mwanthi *et al* 2023, Waongo *et al* 2024).

Economically, afforestation creates opportunities in forestry and carbon markets (Nkonya *et al* 2016), but it risks reducing farmland and exacerbating food insecurity (Chia *et al* 2020). Although initiatives like REDD+ and carbon markets provide financial incentives (FAO 2022), their effectiveness depends on governance structures and equitable benefit distribution (Angelsen *et al* 2012). Socially, afforestation can lead to land tenure conflicts and disrupt local livelihoods (Ribot and Peluso 2003), underscoring the need for policies that integrate agricultural needs and ensure fair benefit-sharing (Lambin and Meyfroidt 2011, Leach *et al* 2012). Environmentally, afforestation can enhance rainfall patterns and mitigate extreme heat (Lawrence and Vandecar 2015), though its effects vary with vegetation type and density (Ingrosso and Pausata 2024, Sy *et al* 2024). However, large-scale plantations may deplete groundwater resources, while native species can restore ecosystems (Brancalion *et al* 2019). Conversely, monoculture plantations often degrade soil health and biodiversity (Barlow *et al* 2007). Although afforestation contributes to carbon sequestration (Bastin *et al* 2019), its success depends on species selection and management practices (Sy *et al* 2024). A balanced approach, integrating ecological and socio-economic considerations, is essential to maximize benefits while minimizing risks.

3.6. Uncertainties in simulated temperature responses

Various LCC-induced compensating phenomena, simulated differently in different model simulations, can influence the magnitude and direction of temperature responses (see figure 2(b)). These include: (i) local/regional physical mechanisms, such as changes driven by albedo-induced cooling effects versus evapotranspiration-induced warming effects (see figure S3) (Sy and Quesada 2020, Sy *et al* 2024). (ii) Variability in how models treat non-local effects (Hirsch *et al* 2014, Chen and Dirmeyer 2016, Winckler *et al* 2017, Chen *et al* 2022). For example, deforestation in one region can influence climate patterns in another, but the magnitude and nature of these influences can differ significantly between models; (iii) model resolution can also affect the simulation of temperature changes, especially in orographic regions (Iles *et al* 2020). The difference may be due to the ability of RCMs to capture finer-scale biophysical effects of LCC that GCMs may miss. However, this increased resolution may also introduce additional uncertainties related to local processes that are less critical at the global scale (Sy *et al* 2023). In addition, each model incorporates its own set of assumptions, parameterizations and simplifications (Rounsevell *et al* 2014, Glotfelty *et al* 2021). These include how LCC information and crop phenology are represented in LSMs (Pitman *et al* 2009, Boisier *et al* 2012, Sy *et al* 2017, Sy and Quesada 2020), the methods used to integrate LCC into background land cover, and the datasets used to characterize current or potential natural vegetation (De Noblet-Ducoudré *et al* 2012). These factors can influence both the magnitude and effectiveness of the energy fluxes exchanged between the surface and the atmosphere (Rounsevell *et al* 2014, Boone *et al* 2016, Sy *et al* 2017). Finally, recent simulations from studies published after 2018 generally show lower climate sensitivity than those from studies published before 2017 (figure S1). Differences in experimental design, particularly the spatial scale and extent of reforestation and afforestation, play a crucial role in shaping model responses (Ingrosso and Pausata 2024, Sy *et al* 2024). For instance, large-scale afforestation efforts tend to have more pronounced impacts due to their stronger influence on land–atmosphere interactions, whereas smaller-scale afforestation projects are more localized and may have less significant effects on temperature. These factors should be carefully considered when interpreting model discrepancies.

3.7. Uncertainties in simulated precipitation responses

Uncertainties in simulated precipitation responses to LCC can be attributed to various mechanisms, primarily those related to changes in evapotranspiration and moisture availability (Seneviratne *et al* 2010, Boone *et al* 2016, Perugini *et al* 2017, Quesada *et al* 2017, IPCC-SRCCL 2019, Ingrosso and Pausata 2024). These mechanisms are typically simulated differently across models, leading to significant discrepancies. For example, different climate models use different parameterization schemes for key processes affecting precipitation, such as convection, cloud formation, and precipitation dynamics (Boone *et al* 2016). Glotfelty *et al* (2021) attribute differences in precipitation response to LCC to a possible underrepresentation of moisture recycling in atmospheric model configurations. This underrepresentation can result in insufficient moisture convergence or inadequate activation of the cumulus parameterization, leading to excess water vapor forming cloud cover instead of precipitation (Wang *et al* 2016). Discrepancies in precipitation response can also be linked to how the African easterly jet is represented, including different meridional shifts and variations in the strength of these shifts among models (Boone *et al* 2016). The interaction between land surface properties and the atmosphere is complex, and its representation varies widely across different models (Sy *et al* 2017). Differences in how land–atmosphere exchanges, such as heat and moisture fluxes, are modeled can lead to discrepancies in simulated precipitation responses (Pitman *et al* 2009, De Noblet-Ducoudré *et al* 2012). For example, the net effect on total evaporation due to LCC is uncertain because different models balance evaporative responses with net radiation changes in various ways (Pitman *et al* 2009). This uncertainty may depend on how models represent complex vegetation–atmosphere interactions, the strength of land–atmosphere coupling, and vegetation parameterization (Koster *et al* 2006, Pitman *et al* 2009, Rounsevell *et al* 2014, Sy *et al* 2017). Moreover, feedback processes between LCC and climate, such as changes in surface albedo, evapotranspiration, and heat fluxes, can amplify or moderate precipitation changes. Models vary in their representation and sensitivity to these feedback mechanisms, leading to different magnitudes and directions in simulated precipitation responses (Pitman *et al* 2009). In addition, large-scale afforestation plays a crucial role in improving regional moisture recycling and cloud formation, while smaller-scale projects tend to have more localized and less pronounced effects. In particular, large-scale afforestation can induce significant changes in local microclimates, increasing humidity and altering precipitation patterns, whereas smaller-scale interventions may have more limited climatic impacts. These differences in scale contribute to variations in model responses and should be considered when interpreting discrepancies in simulation results. In addition, most studies in West Africa have relied on prescribed vegetation models (see table 2), which may not fully capture the dynamic feedback between vegetation and climate. In contrast, dynamic vegetation models allow for interactive vegetation-climate processes, providing a more comprehensive representation of feedback mechanisms (e.g. Sy *et al* 2017).

While modeling approaches can produce similar broad-scale trends, the choice of model configuration can significantly influence results, particularly in regions such as West Africa, where the vegetation-climate coupling is strong (Koster *et al* 2004, 2006). Moreover, most of the experiments analyzed in this study rely on PC models (see table 1), which simplify convective processes and may underestimate the intensity and spatial variability of precipitation. In contrast, CP models, although often limited to smaller spatial domains or shorter simulation periods due to computational constraints, explicitly resolve convection and can provide more accurate precipitation simulations, especially in convective-dominated regions such as West Africa (Kendon *et al* 2012, Marsham *et al* 2013, Stein *et al* 2015, Stratton *et al* 2018, Lucas-Picher *et al* 2021, Crook *et al* 2023). CP also improves the diurnal cycle and spatial distribution of convection (Birch *et al* 2014b) and yields more accurate timing and intensity of monsoonal rainfall (Birch *et al* 2014a). Additionally, turning off convection parameterization improves cloud and precipitation representation by reducing excessive daytime convection (Stein *et al* 2015). However, studies using CP models suggest that their response to soil moisture-precipitation interactions may be different from, or even opposite to, that of PC models (Hohenegger *et al* 2009, Taylor *et al* 2013, Crook *et al* 2023). Recent evidence suggests that while CP and PC models produce qualitatively similar responses of the monsoon circulation to increased vegetation cover over West Africa, CP models tend to show a more pronounced effect (Jungandreas *et al* 2023). These differences in model parameterization may contribute to variations in simulation results and should be carefully considered in future studies.

4. Limitations and future research

A significant limitation in this review is the lack of standardized definitions for the West African region across ESMs (Boone *et al* 2016, Sy *et al* 2017, Sy and Quesada 2020, Glotfelty *et al* 2021, Achugbu *et al* 2023, Mwanthi *et al* 2023). This inconsistency in regional delineation likely contributes to discrepancies in findings across studies, as differences in geographic boundaries, spatial scales, and criteria used to define regions can significantly affect the comparison of LCC effects. Additionally, methodological differences, dataset inconsistencies, and variability in observed signals further complicate cross-study comparisons. Furthermore, variations in simulation periods, the extent of LCC scenarios—whether idealized or realistic—and differences in future emission scenarios may also influence results, as the strength of LCC effects can evolve over time. Addressing these discrepancies is essential to enhance the robustness and comparability of future research. For example, one study might use political boundaries, while another uses ecological zones, leading to variations in LCC's extent and spatial distribution. These inconsistencies may affect the accuracy and comparability of estimates regarding the regional biophysical effects of LCC, resulting in discrepancies in reported impacts on temperature and precipitation. Assessing the scale-dependence of LCC impacts is also complex, as localized effects may be more pronounced at smaller scales, while larger scales might average out these impacts. This lack of standardization complicates efforts to generalize conclusions about LCC effects on regional climates. To address these limitations, it is crucial to establish standardized definitions and criteria for regional boundaries in climate model experiments. This involves developing agreed-upon geographic, ecological, or climatic parameters that can be uniformly applied across studies. Additionally, incorporating methods to assess the scale-dependence of LCC effects could provide more nuanced insights into how these impacts vary with different spatial extents. Improving standardization and methodological approaches will enable future research to quantify better and compare the biophysical effects of LCC, leading to more robust and actionable findings. Furthermore, the limited selection of keywords (see table S3) and poorly written abstracts may have excluded important papers from the review. Additionally, the exclusion of papers published in languages other than English, such as French—which is widely spoken in West Africa—could also restrict the scope of this study

While our study provides valuable insights into the impacts of LCC on mean temperature and precipitation, it has certain limitations. Specifically, our analysis is constrained by the limited number of studies examining changes in climate extremes in response to LCC, most of which focus on afforestation. This gap highlights a critical area for future research, as understanding the effects of LCC on climate extremes—such as heatwaves, floods, droughts, and heavy rainfall is essential for comprehensive climate risk assessment and adaptation planning. For instance, while afforestation may reduce aridity and enhance rainfall extremes in West Africa (Ingrosso and Pausata 2024), it can also lower surface albedo, leading to localized warming and increased heat extremes, particularly during the pre-monsoon season (Saley *et al* 2019, Ingrosso and Pausata 2024, Sy *et al* 2024). These competing effects underscore the need for further research to refine afforestation strategies, ensuring maximum climate benefits while minimizing unintended consequences in West Africa.

The study also highlights significant uncertainties in the simulated impacts of LCC on regional climate in West Africa. These uncertainties might arise from various sources, such as model assumptions, parameterizations, simplifications, resolution, and representations of local and non-local processes, as well as direct and indirect effects, resulting in a wide range of model simulation results (Boone *et al* 2016 Perugini *et al* 2017, Quesada *et al* 2017, Sy *et al* 2017, Sy and Quesada 2020, Glotfelty *et al* 2021). The inter-model spread underscores the complexity of accurately simulating the biophysical impacts of LCC. It also highlights the need for careful interpretation of model results, posing challenges for policymakers relying on model projections to make informed decisions about land use, climate adaptation, and mitigation strategies.

Overall, the results of the study are critical for policy assessment and highlight the importance of incorporating LCC-related climate change metrics into comprehensive climate assessments. To improve the accuracy of climate projections, it is essential to address the mechanisms that drive uncertainties in LCC impacts. Achieving this goal will require a concerted effort within the climate modeling communities. This effort should begin with a coordinated assessment of the representation of LCCs and how well climate models capture their effects in offline and coupled climate models. This, in turn, will inform more effective climate adaptation and mitigation strategies and ultimately support sustainable land management in West Africa.

5. Concluding remarks

This study presents the first comprehensive synthesis of the global literature on the regional biophysical impacts of LCC in West Africa, focusing on simulated changes in surface air temperature and precipitation. It also addresses key uncertainties in the quantification of these impacts on regional climate. Using the PRISMA protocol, nearly 6000 articles were reviewed, and information from 26 selected publications was synthesized. The results indicate that deforestation generally leads to regional warming, with an increase of $+0.26 \pm 0.12$ °C for historical period and $+0.88 \pm 0.25$ °C for future deforestation scenarios. In contrast, afforestation tends to lead to regional cooling, with temperature decreases of -0.24 ± 0.14 °C in the historical period and -0.22 ± 0.14 °C in the future. In terms of precipitation, deforestation is associated with a regional decrease in rainfall, averaging -47 ± 29 mm yr^{-1} in the historical period and a more pronounced decrease of -55 ± 102 mm yr^{-1} projected for the future. Conversely, afforestation is associated with increased precipitation, with increases of up to $+40 \pm 67$ mm yr^{-1} historically and 80 ± 58 mm yr^{-1} in the future.

Data availability statement

All data that support the findings of this study are included within the article (and any supplementary files).

Acknowledgment

The authors thank the German Federal Ministry of Research, Technology and Space (BMFTR) for funding this study through the West African Science Service Center on Climate Change and Adapted Land Use (WASCAL, KNUST) and the Concerted Regional Modelling and Observation Assessment for Greenhouse Gas Emissions and Mitigation Options under Climate and Land Use Change in West Africa (CONCERT-West Africa, Grant No. 01LG2089A). They also thank the Interdisciplinary Centre for Climate Change (iCLIMATE) at Aarhus University for supporting a short research visit to Aarhus University during this project. The authors would like to thank the two anonymous reviewers for their constructive feedback, which significantly improved the quality of the paper.

Contributions

Abdel Nassirou Yahaya Seydou and Souleymane Sy designed the study. Abdel Nassirou Yahaya Seydou and Souleymane Sy carried out data screening, collection, and analysis. Souleymane Sy wrote the manuscript. All authors contributed their expertise and made substantial improvements to the manuscript through discussions and revisions.

Conflict of interest

The authors declare no competing financial interests.

ORCID iDs

Abdel Nassirou Yahaya Seydou https://orcid.org/0009-0009-3971-8486
Souleymane Sy https://orcid.org/0000-0001-8834-7620
Benjamin Quesada https://orcid.org/0000-0002-8827-4801
Jan Bliefernicht https://orcid.org/0000-0002-8591-6231
Kiril Manevski https://orcid.org/0000-0003-2068-3040
Leonard K Amekudzi https://orcid.org/0000-0002-2186-3425
Emmanuel K Appiah-Adjei https://orcid.org/0000-0001-8774-6750
Kehinde O Ogunjobi https://orcid.org/0009-0009-2893-2284
Bouba Traore https://orcid.org/0000-0002-4458-6440
Charles Gyamfi https://orcid.org/0000-0001-7193-4992
Harald Kunstmann https://orcid.org/0000-0001-9573-1743

References

Abiodun B J, Adeyewa Z D, Oguntunde P G, Salami A T and Ajayi V O 2012a Modeling the impacts of reforestation on future climate in West Africa *Theor. Appl. Climatol.* **110** 77–96

Abiodun B J, Pal J S, Afiesimama E A, Gutowski W J and Adedoyin A 2008 Simulation of West African monsoon using RegCM3 Part II: impacts of deforestation and desertification *Theor. Appl. Climatol.* **93** 245–61

Abiodun B J, Salami A T, Matthew O J and Odedokun S 2012b Potential impacts of afforestation on climate change and extreme events in Nigeria *Clim. Dyn.* **41** 277–93

Achugbu I C, Laux P, Olufayo A A, Balogun I A, Dudhia J, Arnault J, Gbode I E, Naabil E and Kunstmann H 2023 The impacts of land use and land cover change on biophysical processes in West Africa using a regional climate model experimental approach *Int. J. Climatol.* **43** 1731–55

Achugbu I C, Olufayo A A, Balogun I A, Adefisan E A, Dudhia J and Naabil E 2021 Modeling the spatiotemporal response of dew point temperature, air temperature and rainfall to land use land cover change over West Africa *Model. Earth Syst. Environ.* **8** 173–98

Almazroui M, Saeed F, Saeed S, Nazrul Islam M, Ismail M, Klutse N A B and Siddiqui M H 2020 Projected change in temperature and precipitation over Africa from CMIP6 *Earth Syst. Environ.* **4** 455–75

Angelsen A, Brockhaus M, Sunderlin W D and Verchot L V (eds) 2012 *Analysing REDD + Challenges and Choices* (CIFOR)

Araza A, Perez M, Cruz R V, Aggabao L F and Soyosa E 2021 Probable streamflow changes and its associated risk to the water resources of Abuan watershed, Philippines caused by climate change and land use changes *Stoch. Environ. Res. Risk Assess.* **35** 389–404

Arfasa G F, Owusu-Sekyere E, Doke D A and Aygei Ampofo J 2024 Impacts of climate and land use/cover changes on the sustainability of irrigation water in West Africa: a systematic review *All Earth* **36** 1–13

Arnault J *et al* 2023 Regional water cycle sensitivity to afforestation: synthetic numerical experiments for tropical Africa *Front. Clim.* **5** 1233536

Arora V K and Montenegro A 2011 Small temperature benefits provided by realistic afforestation efforts *Nat. Geosci.* **4** 514–8

Avila F B, Pitman A J, Donat M G, Alexander L V and Abramowitz G 2012 Climate model simulated changes in temperature extremes due to land cover change *J. Geophys. Res. Atmos.* **117** 1–19

Bala G, Caldeira K, Wickett M, Phillips T J, Lobell D B, Delire C and Mirin A 2007 Combined climate and carbon-cycle effects of large-scale deforestation *Proc. Natl Acad. Sci. USA* **104** 6550–5

Bamba A, Diallo I, Touré N D E, Kouadio K, Konaré A, Dramé M S, Diedhiou A, Silué S, Doumbia M and Tall M 2019 Effect of the African greenbelt position on West African summer climate: a regional climate modeling study *Theor. Appl. Climatol.* **137** 309–22

Barlow J *et al* 2007 Quantifying the biodiversity value of tropical primary, secondary, and plantation forests *Proc. Natl Acad. Sci. USA* **104** 18555–60

Barros V, Mastrandrea M D, Abdrabo M A and Adger W N 2014 Climate change 2014: impacts, adaptation, and vulnerability—IPCC WGII AR5 summary for policymakers *BMJ* **349** 5945

Barry A A *et al* 2018 West Africa climate extremes and climate change indices *Int. J. Climatol.* **38** e921–e38

Bastin J, Finegold Y, Garcia C and Mollicone D 2019 The global tree restoration potential *Restor. Ecol.* **79** 76–79

Bathiany S, Claussen M, Brovkin V, Raddatz T and Gayler V 2010 Combined biogeophysical and biogeochemical effects of large-scale forest cover changes in the MPI earth system model *Biogeosciences* **7** 1383–99

Biasutti M 2019 Rainfall trends in the African Sahel: characteristics, processes, and causes *Wiley Interdiscip. Rev. Clim. Change* **10** 1–22

Birch C E, Marsham J H, Parker D J and Taylor C M 2014a The scale dependence and structure of convergence fields preceding the initiation of deep convection *Geophys. Res. Lett.* **41** 4769–76

Birch C E, Parker D J, Marsham J H, Copsey D and Garcia-Carreras L 2014b A seamless assessment of the role of convection in the water cycle of the West African Monsoon *J. Geophys. Res. Atmos.* **119** 2890–912

Bliefernicht J *et al* 2018 The WASCAL hydrometeorological observatory in the Sudan Savanna of Burkina Faso and Ghana *Vadose Zone J.* **17** 1–20

Boisier J P, De Noblet-Ducoudré N, Pitman A J, Cruz F T, Delire C, Van Den Hurk B J J M, Van Der Molen M K, Mller C and Voldoire A 2012 Attributing the impacts of land-cover changes in temperate regions on surface temperature and heat fluxes to specific causes: results from the first LUCID set of simulations *J. Geophys. Res. Atmos.* **117** 1–16

Bonan G B 2008 Forests and climate change: forcings, feedbacks, and the climate benefits of forests *Science* **320** 1444–9

Boone A A *et al* 2016 The regional impact of land-use land-cover change (LULCC) over West Africa from an ensemble of global climate models under the auspices of the WAMME2 project *Clim. Dyn.* **47** 3547–73
Brancalion P H S *et al* 2019 Global restoration opportunities in tropical rainforest landscapes *Sci. Adv.* **5** eaav3223
Breil M, Davin E L and Rechid D 2021 What determines the sign of the evapotranspiration response to afforestation in European summer? *Biogeosciences* **18** 1499–510
Camara M, Diba I and Diedhiou A 2022 Effects of land cover changes on compound extremes over West Africa using the regional climate model RegCM4 *Atmosphere* **13** 421
Carr T W, Mkuhlani S, Segnon A C, Ali Z and Zougmoré R 2022 Climate change impacts and adaptation strategies for crops in West Africa : a systematic review OPEN ACCESS Climate change impacts and adaptation strategies for crops in West Africa : a systematic review
Charney J G 1975 Dynamics of deserts and drought in the Sahel *Q. J. R. Meteorol. Soc.* **101** 193–202
Chen C, Ge J, Guo W, Cao Y, Liu Y, Luo X and Yang L 2022 The biophysical impacts of idealized afforestation on surface temperature in China: local and nonlocal effects *J. Clim.* **35** 4233–52
Chen L and Dirmeyer P A 2016 Adapting observationally based metrics of biogeophysical feedbacks from land cover/land use change to climate modeling *Environ. Res. Lett.* **11** 034002
Chen L and Dirmeyer P A 2019 The relative importance among anthropogenic forcings of land use/land cover change in affecting temperature extremes *Clim. Dyn.* **52** 2269–85
Chen L and Dirmeyer P A 2020 Reconciling the disagreement between observed and simulated temperature responses to deforestation *Nat. Commun.* **11** 1–10
Chia R W, Son Y, Cho W, Lee Y G, Chia R W, Son Y, Cho W and Lee Y G 2020 Do different land use changes in a deciduous forest ecosystem result in alterations in soil organic C and total N stocks ? *Plant Soil* **457** 153–65
Chilukoti N and Xue Y 2020 An assessment of potential climate impact during 1948–2010 using historical land use land cover change maps *Int. J. Climatol.* **41** 295–315
Christidis N, Stott P A, Hegerl G C and Betts R A 2013 The role of land use change in the recent warming of daily extreme temperatures *Geophys. Res. Lett.* **40** 589–94
Cochrane M A and Laurance W F 2008 Synergisms among fire, land use, and climate change in the Amazon *Ambio* **37** 522–7
Cook K H and Vizy E K 2015 Detection and analysis of an amplified warming of the Sahara Desert *J. Clim.* **28** 6560–80
Cook-Patton S C *et al* 2020 Mapping carbon accumulation potential from global natural forest regrowth *Nature* **585** 545–50
Crook J, Klein C, Folwell S, Taylor C M, Parker D J, Bamba A and Kouadio K 2023 Effects on early monsoon rainfall in West Africa due to recent deforestation in a convection-permitting ensemble *Weather Clim. Dyn.* **4** 229–48
Crook J, Klein C, Folwell S, Taylor C M, Parker D J, Stratton R and Stein T 2019 Assessment of the representation of West African storm lifecycles in convection-permitting simulations *Earth Space Sci.* **6** 818–35
Davin E L *et al* 2020 Biogeophysical impacts of forestation in Europe: first results from the LUCAS (Land Use and Climate across Scales) regional climate model intercomparison *Earth Syst. Dyn.* **11** 183–200
Davin E L and Noblet-Ducoudre N 2010 Climatic impact of global-scale deforestation: radiative versus nonradiative processes *J. Clim.* **23** 97–112
De Noblet-Ducoudré N *et al* 2012 Determining robust impacts of land-use-induced land cover changes on surface climate over North America and Eurasia: results from the first set of LUCID experiments *J. Clim.* **25** 3261–81
Diasso U and Abiodun B J 2017 Future impacts of global warming and reforestation on drought patterns over West Africa *Theor. Appl. Climatol.* **133** 647–62
Diba I, Camara M and Sarr A B 2016 Impacts of the Sahel-Sahara interface reforestation on West African Climate : intraseasonal variability and extreme precipitation events *Adv. Meteorol.* **2016** 1–20
Diba I, Camara M, Sarr A B and Diedhiou A 2018 Potential impacts of land cover change on the interannual variability of rainfall and surface temperature over West Africa *Atmosphere* **9** 376
Doelman J C *et al* 2020 Afforestation for climate change mitigation: potentials, risks and trade-offs *Glob. Change Biol.* **26** 1576–91
Duku C and Hein L 2021 The impact of deforestation on rainfall in Africa: a data-driven assessment *Environ. Res. Lett.* **16** 064044
Duveiller G, Caporaso L, Abad-Viñas R, Perugini L, Grassi G, Arneth A and Cescatti A 2020 Local biophysical effects of land use and land cover change: towards an assessment tool for policy makers *Land Use Policy* **91** 104382
Duveiller G, Hooker J and Cescatti A 2018a A dataset mapping the potential biophysical effects of vegetation cover change *Sci. Data* **5** 1–15
Duveiller G, Hooker J and Cescatti A 2018b The mark of vegetation change on Earth's surface energy balance *Nat. Commun.* **9** 679
Enu K B, Zingraff-Hamed A, Rahman M A, Stringer L C and Pauleit S 2023 Review article: potential of nature-based solutions to mitigate hydro-meteorological risks in sub-Saharan Africa *Hazards Earth Syst. Sci.* **23** 481–505
Falloon P D, Dankers R, Betts R A, Jones C D, Booth B B B and Lambert F H 2012 Role of vegetation change in future climate under the A1B scenario and a climate stabilisation scenario, using the HadCM3C Earth system model *Biogeosciences* **9** 4739–56
FAO 2022 From reference levels to results: REDD+ reporting by countries
Findell K L, Berg A, Gentine P, Krasting J P, Lintner B R, Malyshev S, Santanello J A and Shevliakova E 2017 The impact of anthropogenic land use and land cover change on regional climate extremes *Nat. Commun.* **8** 1–9
Fiorenza M, Duradoni M, Barbagallo G and Guazzini A 2023 Implicit association test (IAT) toward climate change: a PRISMA systematic review *Curr. Res. Ecol. Soc. Psychol.* **4** 100103
Fuller D O and Ottke C 2002 Land cover, rainfall and land-surface albedo in West Africa *Clim. Change* **54** 181–204
Garcia-Carreras L and Parker D J 2011 How does local tropical deforestation affect rainfall? *Geophys. Res. Lett.* **38** 1–6
Glotfelty T, Ramírez-Mejía D, Bowden J, Ghilardi A and West J J 2021 Limitations of WRF land surface models for simulating land use and land cover change in Sub-Saharan Africa and development of an improved model (CLM-AF v. 1.0) *Geosci. Model. Dev.* **14** 3215–49
Guug S, Sy S, Quansah E, Bliefernicht J, Neidl F, Steinbrecher R and Kunstmann H 2025 Methane emissions from rice cultivation in West Africa and compensation options from nature reserve forests *Environ. Res. Lett.* **20** 044050
Harper A B *et al* 2018 Land-use emissions play a critical role in land-based mitigation for Paris climate targets *Nat. Commun.* **9** 2938
Harper N J, Fernee C R and Gabrielsen L E 2021 Nature's role in outdoor therapies: an umbrella review *Int. J. Environ. Res. Public Health* **18** 5117
Hartley A, Jones R and Janes T 2015 Protected areas resilient to climate change PAECC West Africa
Herrmann S M, Brandt M, Rasmussen K and Fensholt R 2020 Accelerating land cover change in West Africa over four decades as population pressure increased *Commun. Earth Environ.* **1** 1–10
Hirsch A L, Pitman A J and Kala J 2014 The role of land cover change inmodulating the soil moisture-temperature land-atmosphere coupling strength over Australia *Geophys. Res. Lett.* **41** 5883–90

Hohenegger C, Brockhaus P, Bretherton C S and Scha C 2009 The soil moisture—precipitation feedback in simulations with explicit and parameterized convection *J. Clim.* **22** 5003–20

Idrissou M, Diekkrüger B, Tischbein B, de Hipt F O, Näschen K, Poméon T, Yira Y and Ibrahim B 2022 Modeling the impact of climate and land use/land cover change on water availability in an inland valley catchment in Burkina Faso *Hydrology* **9** 12

Iles C E, Vautard R, Strachan J, Joussaume S, Eggen B R and Hewitt C D 2020 The benefits of increasing resolution in global and regional climate simulations for European climate extremes *Geosci. Model. Dev.* **13** 5583–607

Ingrosso R and Pausata F S R 2024 Contrasting consequences of the great green wall: easing aridity while increasing heat extremes *One Earth* **7** 455–72

IPCC-SRCCL 2019 Climate change and land: an IPCC special report *Climate Change and Land: an IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems* (available at: www.ipcc.ch/srccl/)

IPCC-SREX 2012 Managing the risks of extreme events and disasters to advance climate change adaptation (SREX). IPCC special report *J. Epidemiol. Community Health* **66** 759–60

Iyakaremye V, Zeng G, Yang X, Zhang G, Ullah I, Gahigi A, Vuguziga F, Asfaw T G and Ayugi B 2021a Increased high-temperature extremes and associated population exposure in Africa by the mid-21st century *Sci. Total Environ.* **790** 148162

Iyakaremye V, Zeng G, Siebert A and Yang X 2021b Contribution of external forcings to the observed trend in surface temperature over Africa during 1901–2014 and its future projection from CMIP6 simulations *Atmos. Res.* **254** 105512

Ji Z, Wang G, Yu M and Pal J S 2015 Potential climate effect of mineral aerosols over West Africa: part II—contribution of dust and land cover to future climate change *Clim. Dyn.* **50** 2335–53

Jia G *et al* 2019 Climate change and land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems pp 1–896

Jungandreas L, Hohenegger C and Claussen M 2023 How does the explicit treatment of convection alter the precipitation—soil hydrology interaction in the mid-Holocene African humid period ? *Clim. Past* **19** 637–64

Kayitesi N M, Guzha A C and Mariethoz G 2022 Impacts of land use land cover change and climate change on river hydro-morphology- a review of research studies in tropical regions *J. Hydrol.* **615** 128702

Kendon E J, Roberts N M, Senior C A and Roberts M J 2012 *Realism of Rainfall in a Very High-Resolution Regional Climate Model* pp 5791–806

Koster R D *et al* 2004 Regions of strong coupling between soil moisture and precipitation *Science* **305** 1138–40

Koster R D *et al* 2006 GLACE: the global land-atmosphere coupling experiment. Part I: overview *J. Hydrometeorol.* **7** 590–610

Kumagai T and Porporato A 2012 Drought-induced mortality of a Bornean tropical rain forest amplified by climate change *J. Geophys. Res.: Biogeosci.* **117** 1–13

Lambin E F and Meyfroidt P 2011 Global land use change, economic globalization, and the looming land scarcity *Proc. Natl Acad. Sci. USA* **108** 3465–72

Laux P, Nguyen P N B, Cullmann J and Kunstmann H 2017 Impacts of land-use/land-cover change and climate change on the regional climate in the Central Vietnam *Water Resour. Dev. Manage.* 143–51

Lawrence D and Vandecar K 2015 Effects of tropical deforestation on climate and agriculture *Nat. Clim. Change* **5** 27–36

Leach M, Fairhead J and Fraser J 2012 Green grabs and biochar: revaluing African soils and farming in the new carbon economy *J. Peasant. Stud.* **39** 285–307

Lejeune Q, Davin E L, Gudmundsson L, Winckler J and Seneviratne S I 2018 Historical deforestation locally increased the intensity of hot days in northern mid-latitudes *Nat. Clim. Change* **8** 386–90

Lejeune Q, Seneviratne S I and Davin E L 2017 Historical land-cover change impacts on climate: comparative assessment of LUCID and CMIP5 multimodel experiments *J. Clim.* **30** 1439–59

Lelieveld J, Proestos Y, Hadjinicolaou P, Tanarhte M, Tyrlis E and Zittis G 2016 Strongly increasing heat extremes in the Middle East and North Africa (MENA) in the 21st century *Clim. Change* **137** 245–60

Li Q, Ma M, Wu X and Yang H 2018 Snow cover and vegetation-induced decrease in global albedo from 2002 to 2016 *J. Geophys. Res. Atmos.* **123** 124–38

Lucas-Picher P, Argüeso D, Brisson E, Tramblay Y, Berg P, Lemonsu A, Kotlarski S and Caillaud C 2021 Convection-permitting modeling with regional climate models: latest developments and next steps *Wiley Interdiscip. Rev. Clim. Change* **12** e731

Mahmood R *et al* 2014 Land cover changes and their biogeophysical effects on climate *Int. J. Climatol.* **34** 929–53

Malhi Y, Roberts J T, Betts R A, Killeen T J, Li W and Nobre C A 2008 Climate change, deforestation, and the fate of the Amazon *Science* **319** 169–72

Marsham J H, Dixon N, Garcia-Carreras L, Lister G M S, Parker D J, Knippertz P and Birch C 2013 The role of moist convection in the West African monsoon system: insights from continental-scale convection-permitting simulations *Geophys. Res. Lett.* **40** 1843–9

Masih I, Maskey S, Mussá F E F and Trambauer P 2014 A review of droughts on the African continent: a geospatial and long-term perspective *Hydrol. Earth Syst. Sci.* **18** 3635–49

Meir P, Cox P and Grace J 2006 The influence of terrestrial ecosystems on climate *Trends Ecol. Evol.* **21** 254–60

Mensah J K, Ofosu E A, Yidana S M, Akpoti K and Kabo-bah A T 2022 Integrated modeling of hydrological processes and groundwater recharge based on land use land cover, and climate changes: a systematic review *Environ. Adv.* **8** 100224

Moher D, Liberati A, Tetzlaff J and Altman D G 2009 Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement *BMJ* **339** 332–6

Monerie P A, Fontaine B and Roucou P 2012 Expected future changes in the African monsoon between 2030 and 2070 using some CMIP3 and CMIP5 models under a medium-low RCP scenario *J. Geophys. Res. Atmos.* **117** 1–12

Mortey E M, Annor T, Arnault J, Inoussa M M, Madougou S, Kunstmann H and Nyantakyi E K 2023 Interactions between climate and land cover change over West Africa *Land* **12** 355

Mwanthi A M *et al* 2023 Representation of land–atmosphere coupling processes over Africa in coupled model intercomparison project Phase 6 *Clim. Dyn.* **62** 8389–401

Nakicenovic N and Swart R 2000 Special report on emission scenarios of the intergovernmental panel on climate change *Sustainability* **11** 1 (available at: http://scioteca.caf.com/bitstream/handle/123456789/1091/RED2017-Eng-8ene.pdf?sequence=12&isAllowed=y%0Ahttp://dx.doi.org/10.1016/j.regsciurbeco.2008.06.005%0Ahttps://www.researchgate.net/publication/305320484_SISTEM_PEMBETUNGAN_TERPUSAT_STRATEGI_MELESTARI)

Nicholson S E 2013 The West African Sahel: a review of recent studies on the rainfall regime and its interannual variability *ISRN Meteorol.* **2013** 1–32

Nicholson S E, Funk C and Fink A H 2018 Rainfall over the African continent from the 19th through the 21st century *Glob. Planet. Change* **165** 114–27

Nkonya E, Mirzabaev A and von Braun J 2016 *Economics of Land Degradation and Improvement—A Global Assessment for Sustainable Development* (https://doi.org/10.1007/978-3-319-19168-3_3)

Nouaceur Z and Murarescu O 2020 Rainfall variability and trend analysis of rainfall in West Africa (Senegal, Mauritania, Burkina Faso) *Water* **12** 1754

Noulèkoun F, Khamzina A, Naab J B, Khasanah N, Van Noordwijk M and Lamers J P A 2018 Climate change sensitivity of multi-species afforestation in Semi-Arid Benin *Sustainability* **10** 1–23

Obahoundje S, Youan Ta M, Diedhiou A, Amoussou E and Kouadio K 2021 Sensitivity of hydropower generation to changes in climate and land use in the Mono Basin (West Africa) using CORDEX dataset and WEAP model *Environ. Process.* **8** 1073–97

Odoulami R C, Abiodun B J and Ajayi A E 2018 Modelling the potential impacts of afforestation on extreme precipitation over West Africa *Clim. Dyn.* **52** 2185–98

Oguntunde P G, Abiodun B J, Lischeid G and Merz C 2012 Modelling the impacts of reforestation on the projected hydroclimatology of Niger River Basin, West Africa *Ecohydrology* **7** 163–76

Palmer L 2021 How trees and forests reduce risks from climate change *Nat. Clim. Change* **11** 374–7

Pausata F S R, Gaetani M, Messori G, Berg A, Maia de Souza D, Sage R F and deMenocal P B 2020 The greening of the Sahara: past changes and future implications *One Earth* **2** 235–50

Perugini L, Caporaso L, Marconi S, Cescatti A, Quesada B, De Noblet-Ducoudré N, House J I and Arneth A 2017 Biophysical effects on temperature and precipitation due to land cover change *Environ. Res. Lett.* **12** 053002

Petersson-Bloom L, Leifler E and Holmqvist M 2023 The use of professional development to enhance education of students with autism: a systematic review *Educ. Sci.* **13** 966

Phillips O L *et al* 2009 Drought sensitivity of the amazon rainforest *Science* **323** 1344–7

Pielke R A *et al* 2011 Land use/land cover changes and climate: modeling analysis and observational evidence *Wiley Interdiscip. Rev. Clim. Change* **2** 828–50

Pitman A J *et al* 2009 Uncertainties in climate responses to past land cover change: first results from the LUCID intercomparison study *Geophys. Res. Lett.* **36** 1–6

Pitman A J *et al* 2012 Effects of land cover change on temperature and rainfall extremes in multi-model ensemble simulations *Earth Syst. Dyn.* **3** 213–31

Pongratz J, Reick C H, Raddatz T and Claussen M 2010 Biogeophysical versus biogeochemical climate response to historical anthropogenic land cover change *Geophys. Res. Lett.* **37** 1–5

Potapov P, Turubanova S, Hansen M C, Tyukavina A, Zalles V, Khan A, Song X P, Pickens A, Shen Q and Cortez J 2022 Global maps of cropland extent and change show accelerated cropland expansion in the twenty-first century *Nat. Food* **3** 19–28

Quesada B, Arneth A and De Noblet-Ducoudré N 2017 Atmospheric, radiative, and hydrologic effects of future land use and land cover changes: a global and multimodel climate picture *J. Geophys. Res.* **122** 5113–31

Quillet A, Peng C and Garneau M 2010 Toward dynamic global vegetation models for simulating vegetation-climate interactions and feedbacks: recent developments, limitations, and future challenges *Environ. Rev.* **18** 333–53

Ribot J C and Peluso N L 2003 A theory of access* *Rural Sociol.* **68** 153–81

Roe S *et al* 2021 Land-based measures to mitigate climate change: potential and feasibility by country *Glob. Change Biol.* **27** 6025–58

Rosenstock T S *et al* 2016 The scientific basis of climate-smart agriculture: a systematic review protocol CCAFS Working Paper no. 138 (CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)) (available at: www.ccafs.cgiar.org)

Rounsevell M D A *et al* 2014 Towards decision-based global land use models for improved understanding of the Earth system *Earth Syst. Dyn.* **5** 117–37

Roy P S *et al* 2015 Development of decadal (1985–1995-2005) land use and land cover database for India *Remote Sens.* **7** 2401–30

Russo S, Marchese A F, Sillmann J and Immé G 2016 When will unusual heat waves become normal in a warming Africa? *Environ. Res. Lett.* **11** 1–10

Saley I A, Salack S, Sanda I S, Moussa M S, Bonkaney A L, Ly M and Fodé M 2019 The possible role of the Sahel Greenbelt on the occurrence of climate extremes over the West African Sahel *Atmos. Sci. Lett.* **20** 1–11

Sanogo S, Fink A H, Omotosho J A, Ba A, Redl R and Ermert V 2015 Spatio-temporal characteristics of the recent rainfall recovery in West Africa *Int. J. Climatol.* **35** 4589–605

Seneviratne S I, Corti T, Davin E L, Hirschi M, Jaeger E B, Lehner I, Orlowsky B and Teuling A J 2010 Investigating soil moisture-climate interactions in a changing climate: a review *Earth Sci. Rev.* **99** 125–61

Smiatek G and Kunstmann H 2023 Potential impact of the pan-African Great Green Wall on Sahelian summer precipitation : a global modeling approach with MPAS *Earth Interact.* **22** 220013

Smith C, Baker J C A and Spracklen D V 2023 Tropical deforestation causes large reductions in observed precipitation *Nature* **615** 270–5

Spracklen D V, Baker J C A, Garcia-Carreras L and Marsham J H 2018 The effects of tropical vegetation on rainfall *Annu. Rev. Environ. Resour.* **43** 193–218

Spracklen D V and Garcia-Carreras L 2015 The impact of Amazonian deforestation on Amazon basin rainfall *Geophys. Res. Lett.* **42** 9546–52

Stein T H M, Parker D J, Hogan R J, Birch C E, Holloway C E, Lister G M S, Marsham J H and Woolnough S J 2015 The representation of the West African monsoon vertical cloud structure in the Met Office unified model: an evaluation with CloudSat *Q. J. R. Meteorol. Soc.* **141** 3312–24

Stratton R A, Senior C A and Vosper S B 2018 A Pan-African convection-permitting regional climate simulation with the Met Office unified model : CP4-Africa *J. Clim.* **31** 3485–508

Sy S, Arnault J, Bliefernicht J, Quesada B, Duveiller G, Seydou A N Y and Oussou F E 2024 Afforestation in West Africa: potential benefits and trade-offs on regional climate extremes *Preprint* (https://doi.org/10.21203/rs.3.rs-4594282/v1)

Sy S, De Noblet-ducoudré N, Quesada B, Dieye A M, Gaye A T and Sultan B 2017 Land-surface characteristics and climate in West Africa : models' biases and impacts of historical anthropogenically-induced deforestation *Sustainability* **9** 1–24

Sy S, Madonna F, Serva F, Diallo I and Quesada B 2023 Assessment of NA-CORDEX regional climate models, reanalysis and *in situ* gridded-observational data sets against the US Climate Reference Network *Int. J. Climatol.* **44** 305–27

Sy S and Quesada B 2020 Anthropogenic land cover change impact on climate extremes during the 21st century *Environ. Res. Lett.* **15** 034002

Sylla B, Elguindi N, Giorgi F and Wisser D 2016a Projected robust shift of climate zones over West Africa in response to anthropogenic climate change for the late 21st century *Clim. Change* **134** 241–53

Sylla M B, Nikiema P M, Gibba P, Kebe I and Klutse N A B 2016b Climate change over West Africa: recent trends and future projections *Adaptation to Climate Change and Variability in Rural West Africa* ed J Yaro and J Hesselberg (Springer) (https://doi.org/10.1007/978-3-319-31499-0_3)

Sylla M B, Pal J S, Wang G L and Lawrence P J 2015 Impact of land cover characterization on regional climate modeling over West Africa *Clim. Dyn.* **46** 637–50

Tano A R, Bouo F-X D B, Kouamé J K, Tchétché Y, Zézé S D and Ouattara B 2023 Rainfall variability and trends in West Africa *Atmos. Clim. Sci.* **13** 72–83

Taylor R G, Scanlon B, Döll P, Rodell M, Van Beek R and Wada Y 2013 Ground water and climate change *Nat. Clim. Change* **3** 322–9

Thomson A M *et al* 2011 RCP4.5: a pathway for stabilization of radiative forcing by 2100 *Clim. Change* **109** 77–94

Trisos C H *et al* 2022 Impacts, adaptation and vulnerability. Contribution of working group II to the sixth assess Tiana Bodley, Anne Bowman, Theresa Carr, Sherri Marie Cocchi, michelament report of the intergovernmental panel on climate change *Int. Lawyer* **52** 505–34

UNCCD 2024 Forest initiative restoring peace and trust through nature (available at: www.unccd.int%7Csecretariat@unccd.int)

Van Bavel J 2013 The world population explosion: causes, backgrounds and -projections for the future *Facts, Views & Vision in ObGyn* **5** 281–91 (available at: www.ncbi.nlm.nih.gov/pubmed/24753956%0Awww.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC3987379)

Wang G, Yu M and Xue Y 2015 Modeling the potential contribution of land cover changes to the late twentieth century Sahel drought using a regional climate model: impact of lateral boundary conditions *Clim. Dyn.* **47** 3457–77

Waongo M, Laux P, Coulibaly A, Sy S and Kunstmann H 2024 Assessing the impacts of climate change on rainfed maize production in Burkina Faso, West Africa *Atmosphere* **15** 1438

Ward D S, Mahowald N M and Kloster S 2014 Potential climate forcing of land use and land cover change *Atmos. Chem. Phys.* **14** 12701–24

Westermann S A, Hildebrandt A, Bousetta S, Thober S and Westermann S A 2024 Does dynamically modelled leaf area improve predictions of land surface water and carbon fluxes?-Insights into dynamic vegetation modules pp 5277–303

Winckler J, Reick C H and Pongratz J 2017 Robust identification of local biogeophysical effects of land-cover change in a global climate model *J. Clim.* **30** 1159–76

Windisch M G, Davin E L and Seneviratne S I 2021 Prioritizing forestation based on biogeochemical and local biogeophysical impacts *Nat. Clim. Change* **11** 867–71

Wulfmeyer V, Branch O, Warrach-Sagi K, Bauer H S, Schwitalla T and Becker K 2014 The impact of plantations on weather and climate in coastal desert regions *J. Appl. Meteorol. Climatol.* **53** 1143–69

Zheng X and Eltahir E A B 1997 The response to deforestation and desertification in a model of West African monsoons *Geophys. Res. Lett.* **24** 155–8