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Foreign direct investment and carbon emissions from land use, land-use change, and forestry (LULUCF): empirical evidence from tropical forest countries

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Abstract

Since 1990, global forest area has been reducing; tropical forests have suffered from different anthropogenic and natural factors that account for forest loss. Tropical deforestation is the second driver of anthropogenic emissions; increasing demand and investments in tropical forests drive these emissions. These forests attract significant foreign direct investments, but the effects of these investments on carbon emissions from land use, land-use change, and forestry are not well enshrined in the literature for the countries under study. This paper seeks to analyse the impact of foreign direct investments on carbon emissions from land use, land-use change, and forestry amongst 30 tropical forest countries from 1996 to 2019. The sampled countries were disaggregated by tropical blocs: Amazon, Congo basin, Australasia, and Southeast Asia, and by income levels; low-income, lower-middle, upper-middle, and high-income. The findings reveal a U-shape structure of the impact of FDI on carbon emissions from LULUCF within Congo basin and Amazon countries; at higher levels of FDI, emissions from LULUCF will increase while Australasia and Southeast Asian countries show an inverted U-shape impact, thus at higher levels of FDI, there will be a negative and significant impact on carbon emissions from LULUCF. The income levels reveal an inverted U-shape for low-income and high-income countries and a U-shape for upper-middle-income countries; the impact for lower-middle-income countries is not significant. Overall, for the whole sample, the impact depicts a U-shape. This paper proposes high-level development of environmental conditions for FDI for different sectors that align with country and regional green growth plans. Enhancing national and regional governance systems to enforce decisions and fight corruption effectively can significantly promote green FDI for green growth.

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1 Introduction

Sustainable production, greening landscapes, green growth, and ethical consumers are increasingly used to promote producing goods and services in conditions of zero-net deforestation and reduced carbon emissions (Balboni et al., 2022; Lyons-White et al., 2020). This growing awareness amongst stakeholders comes on the heels of a loss of 437 million hectares of tree cover globally between 2000 and 2021, which equals an 11% reduction of tree cover compared to 2000 and 174Gt of carbon emissions (Global Forest Watch, 2022). Contrary to primarily developed countries where forest cover is increasing, 11.1 million hectares of tropical forest were lost in 2021 (Fleck, 2022). An estimated 420 million hectares of forest have been converted to other land uses since 1990; however, the trend has decreased over the past three decades (FAO & UNEP, 2020). FAO's (2020) State of the forest report also underscores that deforestation rates dropped from 16 million hectares per year in the 1990s to 10 million hectares per year. The same report also highlights that primary forests globally have decreased by over 80 million hectares since 1990. Forestry, agriculture, and other land-use changes are the second-highest greenhouse gas (GHG) emitting sectors after energy, accounting for 23% of net human-induced GHG emissions between 2007 and 2016, with 11% from agricultural production and 12% from additional land-use changes (IPCC, 2019; Smith et al., 2021)). Tree cover loss in tropical countries resulted in an average of 4.8 gigatons of carbon emissions per year between 2015 and 2017 (Harris &Wolosin, 2018).

Forests serve as a carbon sink and are critical for local temperature regulation; this is done through ground shading and water transpiration (Ellison et al., 2017). However, the changes in land use have led to a continuous rise in temperatures and rainfall variability. Thus, its concomitant effects on agricultural productivity and livelihoods put sustainable development a top priority on the global development agenda (IPCC, 2018). Increasing climate change, which manifests through an increase in mean temperatures, desertification, land degradation, and food security, puts global food systems, human and ecosystem health, livelihoods, infrastructure, and land value at risk (IPCC, 2019). With increasing desertification, the tropics and subtropics are expected to be most vulnerable to crop yield (FAO, 2020).

The high deforestation rates are associated with different factors (FAO, 2020; IPCC, 2019). For instance, large-scale land acquisitions (LSLAs) are defined as the purchase of at least 200 hectares of land (Land Matric, 2020). These investments are welcomed in the Global South because they attract foreign direct investments (FDI), potentially enhancing the transfer of technology, job creation, and local development (Chung, 2019). Most countries have developed strategies through their investment promotion agencies to attract FDIs (Narula & Dunning, 2000). These initiatives have proven to be effective in attracting FDI for many countries over the last two decades (Harding & Javorcik, 2011). However, short-term economic gains from FDIs can be adversely affected by potential environmental costs and serious long-term economic issues (Piabuo et al., 2022). Caetano et al. (2022) underscored that with increase in awareness of environmental costs related to FDIs, most developed countries are now promoting "green FDI" that promotes economic growth while mitigating external environmental costs. They underscored that those developing countries with growth-oriented policies will still attract FDIs with high environmental costs. Tropical countries, therefore, stand out as exciting cases to study because they are developing countries with high-growth-oriented policies, and this paper serves as an eye-opener to the environmental impacts of FDIs within tropical countries. Studies such as that of Davies

et al. (2020) assessed the link between large-scale land acquisitions and tropical forests in 15 countries covering Latin America, Sub-Saharan Africa, and Southeast Asia; however, multi-level country analysis on the impacts of FDI on carbon emissions in the tropics is lacking.

Li and Gallagher (2022) stressed that the impacts of land-use change on climate change had not been appropriately considered in the literature. Scientists have underscored that economic factors drive land-use changes, and foreign direct investments are increasingly becoming a key factor in defining landscape dynamics across different regions (Balboni et al., 2022; Lyons-White et al., 2020). Thus, a proper investigation of how FDI affects the environment can better solve the problem from the origin by re-orienting FDI towards land-use changes with social and environmental co-benefits for the regions and economies. However, the tropical countries considered in this paper do not have enough research on the impacts of FDI on carbon emissions from land use, land-use change, and forestry (LULUCF). This paper, therefore, seeks to contribute empirically by investigating how FDI affects emissions from land use, land-use change, and forestry (LULUCF) in selected tropical forest countries. For this to be achieved, answers will be provided to the following research questions;

- What is the impact of FDI on carbon emissions from land use, land-use change, and forestry (LULUCF)?
- Are there differences in impacts between country blocks and income levels?

The tropical forest countries are of significant relevance because they hold the largest forest areas of the globe, are undergoing significant forest loss, and, at the same time, are receiving a lot of FDIs as most of these countries seek higher levels of economic prosperity. Therefore, investigating the impact of FDI on environmental aspects such as carbon emissions in the tropics is critical for two reasons; (1) countries in the tropics depend a lot on agriculture and forests, and a large part of FDIs are directed towards these sectors; thus, a proper investigation of environmental impacts is important in re-oriented green growth pathways. (2) Countries within the tropics are at different levels of economic development with different levels of control for environmental impacts; thus, disaggregating the analysis by income levels will give a better and new appreciation of the environmental impacts of FDI.

2 Literature review

The literature on FDI and the environment oscillates around three stands in the literature. On the one side, it is considered to positively affect the host country's environment, thus respecting the pollution halo hypothesis, which hypothesises that FDI is detrimental to the host country's environment (Al-Mulali et al., 2015; Baek, 2016). Shahbaz et al. (2015) showed that to avoid additional costs and taxes, pollution is transferred from countries with rigorous environmental regulations to countries with light environmental regulations, thus the pollution haven hypothesis. Dou and Han (2019) pointed out that high-mobile industries will easily move to countries with less environmental regulation when environmental laws in host countries become stringent, while low-mobility industries will invest in innovation, research, and development.

The second strand of literature is prone to the Porter hypothesis, which argues that FDI can improve host countries' environmental health by introducing highly efficient new technology that reduces CO_2 emissions through improved energy efficiency (Xu et al., 2019; Zhang & Zhou, 2016a, 2016b). Shen et al. (2020) underscored that the catalyst for the Porter hypothesis is the ability of environmental regulation to direct FDI towards green innovations and green growth. The ability of governments to attract these green FDI and propel green innovations will also depend on the ability of regulations to provide incentives that cover the extra costs and taxes that come with innovation (Chen et al., 2020).

The third strand of literature underscores no impact of FDI on the environment. The findings of Chanran and Tang (2013), who explored the nexus between income, energy, FDI, and carbon emissions using Johansen cointegration and the Granger causality test for five ASEAN countries, show that FDI does not significantly affect the environment. Similarly, Alshubiri and Elheddad (2019) explored the relationship between FDI and carbon emissions in 32 OECD countries using the panel OLS estimator and GMM, with the findings depicting a nonlinear relationship between these variables. Also, Ayamba et al. (2020) confirmed no long-run relationship between FDI and carbon emissions.

2.1 Effects of foreign direct investments on the environment by income levels

It is also essential to explore how FDI affects the CO_2 emissions of countries at different levels of growth. This is because some countries are undergoing structural transformations from agricultural to industrialised economies and others from industrialised to service economies; thus, the impacts of FDI will differ by levels of structural transformations. Shahbaz et al. (2015) investigated high-, middle-, and low-income countries between 1974 and 2011 using the fully modified ordinary least square regression (FMOLS) model; their results underscore the existence of the pollution halo hypothesis, thus the positive impact of FDI on carbon emissions. Shaari et al. (2014) studied 15 developing countries using the vector error correction model (VECM)-based Granger causality test; their results underscore neutrality between CO_2 emissions and FDI. Similar studies by Wang and Wang (2021) on the relationship between trade openness, FDI, and CO_2 emissions show that trade openness reduces environmental degradation amongst lower-middle-income countries and increases environmental degradation amongst upper-middle-income countries.

Baek and Choi (2017) studied the impact of FDI on the environment in 17 Latin American countries by applying dynamic panel analysis. They highlight that FDI inflows increase CO_2 emissions in high-income countries; they also argue that CO_2 emissions turn to increase with growth in middle-income countries. Within the countries, evidence suggests that the relationship between carbon emission and FDI is more significant and positive in high- and medium-income countries in comparison with low-income countries that have a negative correlation (Behera & Dash, 2017) as low-income developing countries are either unable to attract FDI or only attract FDI in the service sector, which causes a lower effect on carbon emission (Agras & Chapman, 1999). Kivyiro and Arminen (2014) also found that in Sub-Saharan Africa, low-income countries have a negative relationship between carbon pollution and FDI, while middle-income countries have a positive relationship, while other studies using the data of high-income developing countries find a positive relationship between FDI and carbon emissions (Zhang & Zhang, 2018).

The pollution halo hypothesis was also confirmed amongst high-income countries by the findings of Shao (2018), who explored the relationship between carbon intensity and FDI by employing GMM estimation for different income groups on a dataset of 188 countries

between 1990 and 2013. A study covering 2001–2017 by Marques and Caetano (2020) also confirmed the existence of the pollution halo hypothesis for high-income countries by studying 21 countries segregated into low-income and high-income countries by applying the panel autoregressive distributed lag (ARDL) methodology. They highlight that high-income countries benefit from FDI and lower emissions both in the short and long run by using environmentally friendly technology and attracting green FDI as a strategy.

2.2 Effects of foreign direct investments on the environment by tropical blocs

Empirical studies investigating the impact of FDI inflows on CO_2 emissions have also revealed controversial results, mainly depending upon the country analysed and/or econometric methodology and data used. Additionally, the result of FDI and CO_2 emissions is limited. One of the main studies on this nexus is that of Pao and Tsai (2011), who examined the long-run relationship in income, energy FDI with CO_2 emissions of BRICs (Brazil, Russia, India, and China) countries by using panel cointegration and causality analysis. Their results showed that FDI has a positive effect on environmental pollution. Hitam and Borhan (2012) analysed the relationship between income, population pressure, inflow and outflow of FDI, and CO_2 emission, in this case, Malaysia, by using the Johansen cointegration method. FDI's negative impact on environmental quality was revealed, concluding that the EKC relationship is valid for the sample. Lee (2009) also found the exact relationship between FDI and CO_2 emissions in Malaysia. Chang (2011) examines the link between income, FDI, and CO_2 emissions in the case of China by using Johansen cointegration and Granger causality tests. The results show no cointegration and causal link between these variables. Merican et al. (2007) examined the relationship between intermediate income, transforming goods for value-added and FDI entry, and CO_2 emissions for Malaysia, Thailand, Indonesia, Singapore, and the Philippines by adopting the ARDL bounds testing approach. They conclude that a long-run level relationship exists between the variables for every state. However, the coefficient of FDI on emission pollution is positive and significant only in South East Asian countries.

Analysis of FDI, CO_2 emissions, economic growth, and energy in Sub-Saharan Africa reveals a uni-directional movement in the long run (Kivyiro & Arminen, 2014). Arouri et al. (2012) investigated the link between CO_2 emissions, energy consumption, and growth 12 North African and Middle East countries between 1981 and 2005. They employed the panel unit roots and cointegration analysis to show a long-run relationship between energy consumption and CO_2 emissions. Evidence of potential reduction in emissions per capita as GDP per capita grows amongst MENA countries is highlighted in this paper. Tenaw (2020) used cross-sectionally augmented autoregressive distributed lag (CS-ARDL) estimator on a sample of 20 major FDI recipients in Africa between 1990 and 2017 to explore the existence of the pollution halo or haven hypothesis. No significant effects were found, thus difficult to validate the existence of pollution halo/haven in Africa; however, cross-country effects show mixed results of pollution haven and halo hypothesis. Sarkodie and Adams (2018) showed the opposite effects of using renewable energy and fossil fuels on the environment in South Africa. Awodumi (2020) used a sample of the Economic Community of West African States (ECOWAS) countries between 1980 and 2016 to explore the impact of FDI on the environment by applying the ARDL model. Their findings underscore the existence of the pollution halo hypothesis for all ECOWAS countries except Sierra Leone, where FDI promotes environmental efficiency in the short run.

The impact of FDI on CO_2 emissions was investigated by Baek and Choi (2017) for 17 Latin American countries; they employed dynamic panel data analysis, and their results confirm the presence of the pollution heaven hypothesis; thus, FDI increases result in an increase in CO_2 emissions. Sapkota and Bastola (2017) studied 14 Latin American countries between 1980 and 2010 using panel fixed and random effects; their findings reveal a positive impact of FDI on CO_2. However, Polloni-Silva (2021) studied FDI and the CO_2 emissions nexus amongst 592 Brazilian municipalities and depicted a negative relationship between FDI and CO_2 emissions. Blanco et al. (2011) studied 18 Latin American countries between 1980 and 2007 using panel granger causality and found no robust causality between FDI and CO_2 emissions. Many studies in Latin America confirmed the pollution haven hypothesis; they argue that multinational companies operating in the region relocate due to low environmental exigencies (Barbier &Hultberg, 2007; Raymond, 2006; Waldkirch &Gopinath, 2008).

Different contexts have explained these differences within countries and governance systems (Borga et al., 2022; Li et al., 2022). The literature review underscores divergent results under different contexts, regions, and income levels; these studies explored the impacts of FDI on the environment, with CO_2 emissions from all sources being the primary indicator of the environment in most studies. Most studies seek to confirm the existence of Porter, pollution halo, or pollution haven hypothesis amongst different countries. Studies exploring the nexus between FDI and carbon emissions from LULUCF are limited. This paper will also contribute to the current scholarly debate on the impacts of FDI on carbon emissions. This paper will enrich the empirical literature by controlling for differences in levels of development and governance of countries within the tropics. The paper also employs a panel systemic GMM model to explore the impacts of FDI on carbon emissions from LULUCF.

3 Methodology

3.1 Model

Building from the literature in the previous section, trade, captured as imports and exports along with FDI, impacts carbon emissions differently in different countries. The Grossman and Krueger (1995) model is adapted to integrate FDI as a key element of economic growth in developing countries. Evidence of a relationship between per capita income and environmental quality was provided by Grossman and Krueger (1995) using the following reduced equation.

$$E_{it} = \beta_0 + \beta_1 Y_{it} + \beta_2 Y_{it}^2 + \beta_3 \tau_{it} + \varepsilon_{it} \tag{1}$$

where E_{it} refers to the indicator of the environment, i represents the country, and t represents the year. This paper uses carbon emissions from LULUCF or, better still, forestry, and other land use (FOLU) as an environmental indicator. This allows us to understand better how FDI and GDP growth affect carbon emissions from FOLU. β_0 represents the constant term; meanwhile, Y and Y^2 are included in the model as independent variables to capture the effect of higher-income levels (captured using FDI and economic growth) on environmental indicators. τ_{it} captures other control variables such as trade openness, forest area, and governance effectiveness. The theoretical foundations highlighted by Salman et al. (2019b) on the relationship between trade and environmental degradation are used to include trade as a key independent variable. They postulate that increased natural resource use is required to increase exports, especially in developing countries. Increasing exports

also requires the attraction of FDI through international companies. This is especially true with developing countries promoting export-led growth and industrialisation through domestic processing of natural resources and agricultural products (Chang et al., 2018; Chapman et al., 1985). Thus, trade and FDI will be used to capture the effect of trade openness and FDI on the environment. Empirical evidence also underscores that the effect of trade and FDI on the environment depends on institutional factors and the choice of trade and FDI a country decides to attract. Salman et al. (2019a) underscored that efficient and effective domestic institutions enhance economic growth while reducing carbon emissions. Building from these, the reduced form equation above will further be developed to capture the different indicators of the environment and independent variables (see Eqs. (2)).

$$
\begin{aligned}
\text{Carbon emission(LULUCF)}_{it} = {} & \beta_0 + \beta_1 \text{GDP growth}_{it} + \beta_2 \text{GDP growth}_{it}^2 \\
& + \beta_3 \text{FDI}_{it} + \beta_4 \text{FDI}_{it}^2 + \beta_5 \text{forest area}_{it} \\
& + \beta_6 \text{Government effectiveness}_{it} + \beta_7 \text{trade}_{it} + \varepsilon_{it}
\end{aligned} \tag{2}
$$

This paper builds on the limitations of studies such as that of Sung and Song (2018) that did not account for institutional factors by using governance effectiveness as an indicator of institutional quality. On this basis, the following sections present data collection sources and a description of the variables.

3.2 Data collection and variables

The sample countries were selected based on their geographical location in the tropics. To further understand how the level of income and governance impact the environment, the segregation of countries within the tropics will be done by the World Bank (2021) classification by incomes. Each year the World Bank classifies countries into four income groups. The new thresholds based on per capita gross national investment (GNI per capita ($)) classify countries as low (< 1085), lower-middle-income (1086–4255), upper-middle-income (4256–13,205), and high-income ($> 13,205$) (World Bank, 2022a). Table 1 summarises the classification of countries into different categories.

Some countries, such as Guam, were not included in the sample due to a lack of data; meanwhile, the sample period was chosen based on data availability. Data from 1996 to 2019 made up this sample covering the 30 countries listed in Table 2 and were obtained from different sources. The variables used to capture institutional quality, i.e. government effectiveness, were obtained from the World Bank Governance Indicators; carbon emissions from LULUCF, agriculture value-added, forest area, and arable land were all obtained from the FAO (2020). Data relating to Foreign Direct Investment (FDI), trade, and economic growth were obtained from the World Bank Indicators (WDI, 2020). Table 2 outlines the variable, description, and source of data.

3.3 Data analysis

3.3.1 System dynamic generalised method of moments (GMM) panel regression model

Several econometric techniques are available in the literature to investigate panel structure data. For univariate cointegration, Phillips and Hansen (1990) and Engle and Granger (1987) fully modified ordinary least square method is often used. However, for

Table 1 Distribution of sampled countries by income countries and tropical blocs

Income levels	Countries	Tropical blocs	Countries
Low-income (02)	Central African Republic, Congo, Dem. Rep	Amazon (08 countries)	Brazil, Bolivia, Peru, Ecuador, Colombia, Venezuela, Guyana, Suriname
Lower-middle-income (07 countries)	Bolivia, Cameroon, Papua New Guinea, Solomon Islands, Philippines, Myanmar, Lao PDR	Congo basin (05 countries)	Cameroon, Central African Republic, the Democratic Republic of the Congo, Equatorial Guinea, Gabon
Upper-middle-income (16 countries)	Brazil, Peru, Ecuador, Colombia, Venezuela, Guyana, Suriname, Equatorial Guinea, Gabon, Fiji, Tonga, Thailand, Malaysia, Indonesia, China	Australasia (08 countries)	Australia, Fiji, New Zealand, Papua New Guinea, Samoa, Solomon Islands, Tonga
High-income (05 countries)	Australia, New Zealand, Samoa, Singapore, Brunei	Southeast Asia (09 countries)	Thailand, Malaysia Indonesia, Philippines, Myanmar, Singapore Brunei, China, Laos

Table 2 Variables and source of data

Variable	Description	Source of data
FDI	Foreign direct investments are the net inflows of investment to acquire a lasting management interest (10 per cent or more of voting stock) in an enterprise operating in an economy other than that of the investor. It is the sum of equity capital, reinvestment of earnings, other long-term capital, and short-term capital, as shown in the balance of payments. This series shows net inflows (new investment inflows less disinvestment) in the reporting economy from foreign investors and is divided by GDP	WDI
GDP growth	The annual percentage growth rate of GDP at market prices is based on constant local currency. Aggregates are based on constant 2010 US dollars. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or depletion and degradation of natural resources	WDI
Forest area	Area of land with planted or natural trees of at least 5 m in situ and excludes tree stands in agricultural systems	FAO STAT
Trade	Trade is the sum of exports and imports of goods and services measured as a share of the gross domestic product	WDI
Government Effectiveness	Reflects perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies	WGI
Carbon emissions (LULUCF)	Covers emissions and removals of greenhouse gases resulting from direct human-induced land use such as settlements and commercial uses, land-use change, and forestry activities	FAO STAT

multivariate cointegration analysis, Johansen and Juselius (1990) and Johansen (1988) full information maximum likelihood methods are used. Although Johansen and Juselius (1990) are often used because they accommodate small sample bias and provide multiple cointegration relationships, they require that all variables be integrated in the same order. In this paper, one-step system GMM estimators were provided by Arellano and Bover (1995) and later developed by Blundell and Bond (1998). This method is appropriate for small cross-sectional entities and long periods. The system GMM is chosen because it controls for endogeneity and is free from measurement errors. The regressors are transformed by differencing; it assumes the first difference of instrumental variables is uncorrelated with fixed effects (Roodman, 2009).

Building from these advantages, the system GMM panel methodology will be employed in this paper using the sample highlighted above to investigate the dynamics between carbon emissions (LULUCF), FDI, trade, and GDP within tropical countries. The empirical model presented in (3) can further be developed, as illustrated in the equations below.

$$\begin{aligned}
\text{Carbon emission LULUCF}_{it} = {} & \alpha_i + \delta_1\text{Carbon emission LULUCF}_{it-i} + \delta_2\text{GDP}_{it-i} + \delta_3 d(\text{GDP})^2_{it-i} \\
& + \delta_4\text{FDI}_{it-i} + \delta_5 d(\text{FDI})^2_{it-i} + \delta_6\text{trade}_{it} + \delta_7\text{forest area}_{it} \\
& + \delta_8\text{governanc effectiveness}_{it} + \varepsilon_{it}
\end{aligned}$$

(3)

δ_1 to δ_8 represent coefficients of variables used, and $it - i$ captures the current and lag periods of the variables. α_i represents country-specific intercept and varies across countries, while ε_{it} is the error term with unit variance and zero means. Variables such as FDI are not exclusively exogenous; thus, causality can run in both directions; additionally, autocorrelation can be produced as a result of the lagged dependent variable; the system one stem GMM method is employed because it controls for these potential econometric issues. To ensure the robustness of estimates, preliminary tests such as the unit roots test and pairwise correlation are used.

3.3.2 Unitary root tests

Unit root tests are used to check whether a series is stationary. A series is stationary if its probability distribution does not change over time. The augmented Dickey–Fuller (ADF) test developed by Im et al. (2003) will be used in this study. The combined I'm, Pesaran and Shin (IPS), and Fisher tests would be employed. However, the additional advantage of the Fisher test over the IPS test is that the Fisher test does not require the panel to be balanced. Another advantage of using this combined test is that it can be applied to series with different lag lengths, the ADF individual regression that would be used in this analysis to test for stationarity.

3.3.3 Pairwise correlation analysis

To have a general overview of the relationship between variables, pairwise correlation analysis was employed. It permits the identification of groups of highly correlated elements; it indicates the strength and direction of the correlation; the coefficient ranges from −1 to +1, indicating perfect positive and negative correlation; 0 indicates no correlation; the closer the value to 1, the stronger the correlation.

4 Results

4.1 Descriptive statistics of the sample

The major findings of this paper are presented in this section. It builds on the theoretical and empirical conceptualisation of the analysis outlined in the methodology. To appropriately contextualise and understand the different regions and income levels for variables of interest, Table 3 shows averages over the study period (1996–2019).

In terms of income levels, foreign direct investment inflows are highest in high-income countries, averaging 5.99% of GDP, followed by upper-middle-income countries (4.23% of GDP), then lower-middle-income (3.10% of GDP) and low-income countries (2.48% of GDP). However, carbon emissions (LULUCF) are highest in low-income countries averaging 231,752.64 kilotonnes. In comparison, lower-middle-income countries recorded a net negative carbon emission (LULUCF) of 27,976.41 kilotonnes. In contrast, upper-middle-income and high-income countries had positive carbon emissions (LULUCF) of 91,795.45 kilotonnes and 6,771.54 kilotonnes, respectively. Figure 1 shows levels of FDI inflows, and the two black lines demarcate the tropical countries to illustrate these interconnections better. It can be seen that FDI inflows are more than 2% of GDP within most tropical countries.

Although low-middle-income countries have the highest average growth rates of 5.08% over the period, they have a net negative emission from land-use change; thus, their growth is not determined by significant land-use changes, while emissions from land-use change are higher for countries with lower growth rates such as low-income countries (2.54%) and high-income countries (2.93%). Governance scores captured by governance effectiveness estimates are best in high-income countries with positive scores and worst in low-income countries with average scores of 1.59 for governance effectiveness. Trade is also highest for high-income countries; the table shows higher levels of trade as income levels increase.

Regarding tropical blocs, FDI inflows are highest in the Congo basin, averaging 6.7%, followed by Southeast Asia with 4.9%, and FDI inflows to Amazon and Australasia average 3.2 and 2.8%, respectively. However, although Southeast Asia is the second highest in FDI inflows, they register an average negative carbon emission (LULUCF) over the study period; meanwhile, Amazon is highest with 146,099.7 kilotonnes, and Congo basin follows with 90,361.5 kilotonnes. Governance indicators in these two regions are equally relatively poor compared to Australasia and Southeast Asia. Fern (2015) explained that 2.4 million hectares were illegally cleared for beef, palm oil, and soy production between 2000 and 2012. In the Congo basin, Tyukavina et al. (2018) highlighted small-scale artisanal forest clearance for agriculture as the primary driver for land-use change and forest cover; selective logging comes second. These land-use changes contribute to the high rates of Carbon emissions (LULUCF). William et al. (2021) also underscored that agricultural expansion into tropical forests remains the primary driver of LULUCF emissions from Africa, Southeast Asia, and Latin America. To further explore how these variables relate, pairwise correlation analysis was done for all the countries in the study.

4.2 Pairwise correlation analysis

Pairwise correlation analysis is employed to understand better how the variables used in this study interact. Table 4 underscores a weak, negative, and significant relationship between foreign direct investment (FDI) and carbon emissions from LULUCF at current

Table 3 Averages by income levels and regional blocs

Income levels

Variable	Low-income countries	Lower-middle income	Upper middle income	High income
Foreign direct investment	2.48	3.10	4.23	5.99
Carbon emissions (LULUCF)	231,752.64	(27,976.41)	91,795.45	6,771.54
GDP growth (annual %)	2.54	5.08	4.45	2.93
Government effectiveness: Estimate	(1.59)	(0.77)	(0.29)	1.36
Trade	51.31	70.37	92.69	128.85

Tropical blocs

Variable	Congo Basin	Amazon	Australasia	Southeast Asia
Foreign direct investment	6.7	3.2	2.8	4.9
Carbon emissions (LULUCF)	90,361.5	146,099.7	15,147.2	(11,020.9)
GDP growth (annual %)	5.3	3.1	2.6	5.4
Government effectiveness: Estimate	(1.2)	(0.4)	0.2	0.2
Trade	81.3	82.4	84.9	114.3
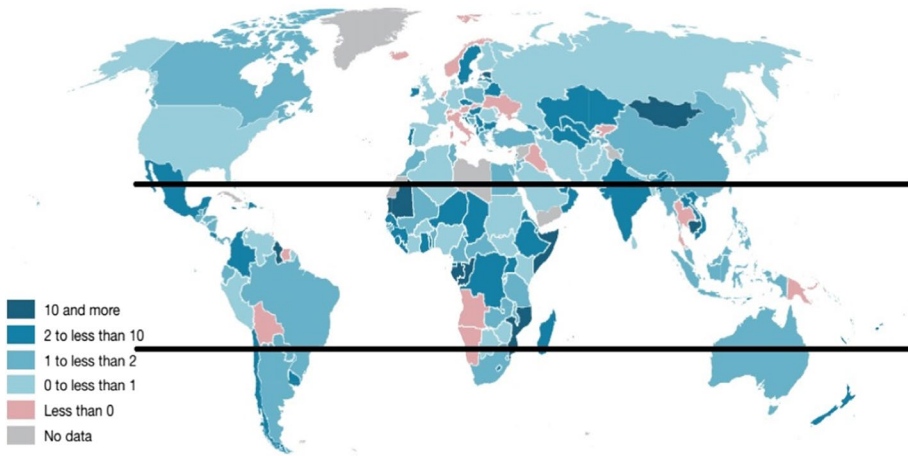
Fig. 1 Foreign direct investment inflows. *Source*: UNCTAD, 2019

levels of FDI; at higher levels of FDI (FDI squared), the relationship is positive but not significant, suggesting the potential existence of an inverted U-shape relationship. This weak and significant relationship is also true for economic growth and carbon emissions, government effectiveness, and carbon emission from LULUCF. Table 4 also shows a weak positive correlation between FDI, economic growth, government effectiveness, and trade.

For the whole sample, this analysis reveals that carbon emissions from LULUCF are negatively correlated with FDI, economic growth, and trade, even at higher-income levels; however, it is a weak negative correlation. Meanwhile, FDI and economic growth correlate negatively with governance effectiveness.

Table 4 Pairwise correlations

Variables	(Carbon Emission)	(FDI)	(FDI Squared)	(GDP growth Annual)	(GDP Squared)	(Forest Area)	(Government effectiveness)	(Trade)
Carbon Emission	1.000							
FDI	-0.051*	1.000						
FDI Squared	-0.020	0.846*	1.000					
GDP growth	-0.062*	0.400*	0.374*	1.000				
GDP Squared	-0.019	0.232*	0.215*	0.832*	1.000			
Forest area	-0.030*	0.066*	-0.037*	-0.085*	-0.074*	1.000		
Government effectiveness	-0.044*	0.080*	-0.033*	-0.048*	-0.067*	0.921*	1.000	
Trade	-0.152*	0.361*	0.096*	0.051*	0.041*	0.353*	0.411*	1.000

*** p<0.01, ** p<0.05, * p<0.1*

4.3 Panel unit roots test

The unit root test provided by Fisher's augmented Dickey–Fuller test and the Im et al. (2003) test are employed to test the stationary properties of variables used in this paper. Table 5 shows that all the variables are stationary at level, thus, are all integrated at order zero I(0).

4.4 System dynamic panel data regression results

Building from the literature and dynamics of FDI, to better appraise the impact of FDI on carbon emissions from LULUCF, the sampled countries were divided into tropical blocs and by income levels. In this section system panel, GMM results will be presented based on tropical blocs and country income levels as defined by the World Bank.

4.4.1 Impact of FDI on carbon emissions by regions along the tropics

The regression Table 6 underscores the results of dynamic panel regression for tropical blocs. Four tropical blocs, Congo basin, Amazon, Australasia, and Southeast Asia, are adopted. The results indicate that emissions from the last two periods explain current levels of carbon emissions from LULUCF. This is evidenced by a positive and significant impact of carbon emissions from lag 1 and 2 on current levels of carbon emissions for all the tropical blogs. As the lag period increases, the impact on current levels of emissions reduces; for all the tropical blocs, impacts of lag (−1) carbon emissions are higher than lag (−2) on current levels of emissions from LULUCF.

The influence of FDI on carbon emissions is not homogenous amongst the country blocs; the Congo basin and Amazon countries show a U-shaped curve; thus, at current levels of FDI, the impact is negative and significant on carbon emissions. However, the impact is positive and significant at higher levels of FDI (FDI squared); thus, increased FDI will lead to higher emissions from LULUCF. The degradation of the primary forest explains this U-shape within the Congo basin forest through forest exploiting companies and subsistence agriculture. The positive and significant impact of forest areas on carbon emissions from LULUCF supports this. Within Congo basin countries, a large

Table 5 Unit root test

Variable	Fisher	IPS	Order of integration
Carbon emission	− 3.4173 (0.000)	− 4.5866 (0.000)	I(0)
FDI	− 6.7013 (0.000)	− 9.3681 (0.000)	I(0)
FDI squared	− 8.6788 (0.000)	− 8.5668 (0.000)	I(0)
GDP growth	− 10.9181 (0.000)	− 10.2335 (0.000)	I(0)
GDP growth squared	− 10.4358 (0.000)	− 10.5302 (0.000)	I(0)
Forest area	− 9.22010 (0.000)	− 9.23542 (0.000)	I(0)
Government effectiveness	− 2.4193 (0.008)	− 5.2683 (0.000)	I(0)
Trade	− 2.7819 (0.000)	− 5.2406 (0.000)	I(0)

Values in parentheses represent probability values for both Fisher and IPS, representing the panel unit root test of Im et al. (2003)

Table 6 Panel results for tropical blocs

Variables	(1) Congo basin countries	(1) Amazon	(1) Australasia	(1) South Asia
L.Carbon_emissions	0.563*** (0.0898)	0.778*** (0.0624)	0.447*** (0.0874)	0.617*** (0.0489)
L2.Carbon_emissions	0.328*** (0.0894)	0.219*** (0.0829)	0.366*** (0.0623)	0.264*** (0.0533)
L3.Carbon_emissions	0.0851 (0.0896)	−0.0271 (0.0785)	0.155** (0.0676)	0.0727 (0.0601)
FDI	−0.00473*** (0.00169)	−0.0132* (0.00750)	0.0187 (0.0142)	0.0109* (0.00574)
FDI squared	8.13e−05* (4.25e−05)	0.000755*** (0.000291)	−0.00179* (0.00101)	−0.000411* (0.000225)
GDP growth	−0.000121 (0.00113)	−0.00211 (0.00744)	0.00594 (0.00646)	0.00908*** (0.00271)
GDP growth squared	−2.38e−05 (2.77e−05)	−0.000913 (0.000800)	0.000277 (0.000708)	−0.000552*** (0.000249)
Forest area	2.27e−06** (1.00e−06)	5.38e−07 (7.11e−07)	−5.19e−06** (2.32e−06)	2.72e−07 (4.70e−07)
Government effectiveness	−0.00568 (0.0433)	−0.104 (0.100)	0.225*** (0.0812)	0.0334 (0.0409)
Trade	0.00106*** (0.000392)	0.00137* (0.000823)	0.00642*** (0.00188)	−0.000150 (0.000390)
Observations	89	163	163	196
Number of countries	5	8	8	9

Standard errors in parentheses

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

share of FDIs are directed towards forest exploitation; in 2010, more than 10% of DRC's dense forest area was under the management of Chinese companies (Putzel et al., 2011). Also, Brack (2014) reported that more than 14 countries are receiving FDI in Africa's agriculture and forestry sector, with Gabon having 23%. Although FDI in agriculture and forestry is expanding amongst Amazon countries, restrictions in land investments for some countries are limiting the expansion. FDI through large-scale land acquisitions (LSLAs) are one of the critical drivers of LULUCF within tropical countries; Mazzocchi et al. (2021) evaluated LSLAs between 2003and 2017, and their analysis revealed that 950 deals were concluded for 37.325.905 ha in Sub-saharan Africa, followed by 792 deals for East Asia/Pacific countries amounting to 21.536.016 ha, Latin America/Caribbean concluded 769 deals for 17.663.599 ha. This underlines the extent of LSLAs within tropical countries.

Countries in Australasia and South East Asia show an inverse U-shape impact of FDI on carbon emissions from LULUCF. At current levels of FDI, the impact is positive and significant for South East Asia but not significant for Australasia. However, at higher levels of FDI (FDI squared), both tropical blocs have a negative and significant impact. Thus, at a higher level of FDI, countries in these blocs will redirect FDI towards green development, and environmental concerns will be higher than growth objectives. The negative and significant impact of forests on carbon emissions from LULUCF illustrates the sensitivity of FDIs to the environment. Thus, the government of these countries are already making significant strides in increasing their forest area and, thus, will not accept future FDIs that lead to reduced forest cover. Although natural disasters such as bushfires significantly affect forest area and LULUCF, the forest area in Australia increased by 3.9 million ha between 2011 and 2016 through forest regrowth and reduction in commercial plantations (ABARES, 2018).

The effect of economic growth on carbon emissions from LULUCF is not significant for all the other tropical blocs except for South East Asian countries that show an inverted shape. At current GDP levels, there is a positive and significant impact on carbon emissions from LULUCF; however, the impact is negative and significant at higher levels of GDP (GDP growth squared). This is principally because palm production is integral to the countries' economies within this region. The countries are already testing and adopting technologies to reduce emissions from palm oil fields and are exploring options for sustainable land use and land-use planning. The impact of trade on carbon emissions from LULUCF is positive and significant for Congo basin countries, Amazon and Australasia. However, the effect is not significant for Southeast Asian countries. Meanwhile, governance effectiveness was not significant for tropical blocs except for Australasia where there is a positive and significant impact; this is probably due to the governance of fire management with increasing incidents of wildfires.

4.4.2 Impact of foreign direct investments (FDI) on carbon emissions from LULUCF by income levels

Carbon emissions from LULUCF also vary based on income levels. The regression results in Table 7 underscore that current levels of carbon emissions from LULUCF are positively affected by emissions from previous years for all income groups except for high-income countries in lag (−2).

The impact of FDI inflows on carbon emissions from LULUCF shows an inverted U-shape for low-income and high-income countries. Meanwhile, the effect is a U-shape for

upper-middle-income countries, with no significant impact for lower-middle-income countries. This is primarily because low-income countries in this sample depend a lot on FDI in agriculture and forestry for economic growth and are attracting funds through FDI to develop this sector. This explains the current increase in emissions; however, these countries understand the long-term impacts of these actions, and policies are being revised and enforced to control the effect on the environment, which explains the inverted U-shape. For high-income countries, current growth outcomes have been constructed to the detriment of the environment. Over the past 05 years, considerable actions have been taken towards green growth and green FDI. Thus, the impact will be negative and significant at higher levels of FDI, as depicted by the regression Table 7. Upper-middle-income countries are still in the perspective of growth. Thus, at higher levels of FDI, there is a positive and significant impact on carbon emissions from LULUCF; therefore, the U-shape structure is a reality for these countries. This result is relevant for the overall sample because 16 countries of the study fall within this group; hence, for the overall sample, the impact of FDI on carbon emissions from LULUCF reflects a U-shape. That is, at current levels of FDI, the impact on carbon emissions from LULUCF is negative and significant. Meanwhile, at higher levels of FDI, the impact is positive and significant for the overall sample.

The impact of GDP growth on lower-middle and upper-middle-income countries shows a U-shape. At current levels of GDP growth, the impact is negative and significant. However, at higher levels of economic growth, the impact is positive and significant. This is predominantly because these countries are at the level where economic growth and employment are critical to their policy agenda, and environmental concerns are relegated to second order. Overall, for the whole sample, there is no impact of GDP growth and GDP growth squared on carbon emissions from LULUCF. Table 7 shows that forest area has a positive and significant impact on the different income groups except for upper-middle-income countries, which depicts a negative and significant impact. This result is reflected in the whole sample with a negative and significant impact of forest area on Carbon emissions on LULUCF. This implies that although changes in the area in some income groups are significant enough to positively contribute to carbon emissions, there is net carbon sequestration from a change in forest area for the global sample. This impact is also due to some tropical countries that have seen an increase in their forest area over the past decades, thus cancelling out the net deforestation in other parts of the tropics and other countries with different income levels.

As expected, governance effectiveness positively and significantly impacts low, low-middle, and upper-middle-income countries. However, there is a negative and significant impact on high-income countries. High-income countries are improving their governance structures and enhancing governance effectiveness by applying strategies to reduce emissions from LULUCF. For example, between 2005 and 2018, emissions from LULUCF in Queensland were reduced by 66%, and South Australia, New South Wales, Western Australia, Victoria, and Tasmania all registered negative net emissions from LULUCF in 2018 (ABARES, 2020). For the whole sample, governance effectiveness negatively and significantly impacts carbon emissions from LULUCF. The findings show a positive and significant impact of trade on carbon emissions for low and upper-middle-income countries. However, the impact is not significant for the other income groups. For the whole sample, trade openness positively and significantly impacts LULUCF. This result suggests that trade drives land-use changes, which leads to higher emissions. Thus, critical actions are required for trade to drive land-use changes towards higher levels of carbon sequestration.

Table 7 Panel results for income levels

Variables	Dependent variable: carbon emissions from LULUCF				
	Low-income countries	Lower-middle-income	Upper-middle-income	High-income	All sample
L.Carbon_emissions	0.960*** (0.112)	−0.404* (0.234)	0.398*** (0.0328)	−0.0250 (0.0529)	0.648*** (0.00685)
L2.Carbon_emissions	−0.279* (0.159)		−0.290*** (0.0143)	0.0357 (0.0509)	0.316*** (0.00161)
L3.Carbon_emissions	0.0946 (0.113)				−0.0879*** (0.00174)
FDI	0.0157*** (0.00513)	−0.00264 (0.00180)	−0.000796*** (0.000221)	0.00122*** (0.000369)	−0.000395*** (0.000162)
FDI squared	−0.00170*** (0.000432)	0.000320 (0.000383)	9.09e−06*** (2.69e−06)	−2.65e−05* (1.55e−05)	5.46e−06* (2.80e−06)
GDP growth	−0.00311* (0.00163)	−0.00585*** (0.00198)	−0.000508*** (0.000110)	3.74e−05 (0.000413)	−0.000139 (9.25e−05)
GDP growth squared	−7.27e−05 (5.38e−05)	0.000412* (0.000221)	6.70e−06*** (1.29e−06)	−2.45e−05 (4.75e−05)	4.31e−07 (2.19e−06)
Forest area	7.15e−07** (2.83e−07)	7.48e−06*** (1.54e−06)	−1.45e−07* (1.39e−07)	5.05e−07*** (5.58e−08)	−3.76e−07*** (1.01e−08)
Governance effectiveness	0.0596*** (0.0199)	0.0194** (0.00990)	0.00478*** (0.00195)	−0.0102*** (0.00302)	−0.00631* (0.00341)
Trade	0.00191*** (0.000457)	−4.39e−05 (0.000118)	0.000302*** (4.79e−05)	−4.30e−05 (5.25e−05)	0.000892*** (3.33e−05)
Observations	40	134	301	98	462
Number of countries	2	7	16	5	30

Standard errors in parentheses

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

5 Discussion

5.1 Foreign direct investments and carbon emissions from land use, land-use change, and forestry (LULUCF)

The findings in this paper align with that of Davies et al. (2020), who underscored that large-scale land acquisitions in the tropics are being granted in forest areas, with more than half of this area related to forest loss since 2000. They further explained that the effect of large-scale land acquisitions on land-use change and carbon emissions from land-use change depends on the type of investments on the land. In the Congo basin, logging and mines are the predominant land uses for large-scale acquisitions. These land uses do have a significant effect on forest cover loss and, thus, deforestation. This explains the negative impact of FDI on carbon emissions from LULUCF amongst Congo basin countries at the current level and a positive and significant effect at higher levels of FDI. However, for Southeast Asia, predominant investments are in oil palm and tree plantations, which results in significant land-use changes and increases carbon emissions from LULUCF. The primary flow has invested in the service sector rather than the primary sector (SBP). This explains FDI's positive but not significant impact on carbon emissions from LULUCF in Southeast Asia. Davies et al. (2020) further explained that the rate of forest loss depends on activities developed with FDIs. Oil palm plantations contribute the highest to forest loss while logging, especially selective logging, is associated with low levels of forest loss. Forest loss from mining depends on the type of mineral being exploited, thus the difference in forest loss from mining in the Congo Basin and South America.

The positive impacts of FDI on Carbon emissions in high-income countries were also confirmed by Zhang and Zhang (2018), who found the relationship between the two to be positive. One of the key differences between this study with other studies is that the dependent variable is carbon emissions from LULUCF; thus, it captures FDIs that lead to LULUCF. Although it may corroborate with other studies that capture carbon emissions from other activities, looking further into the land-use change dynamics and what drives it is essential. Azadi et al. (2020) underscored that agricultural area is decreasing in high-income OECD and non-OECD countries and increasing in the upper-middle, lower-middle, and low-income countries. However, carbon emissions are increasing in countries where agricultural land is declining. Tasser et al. (2017) also confirmed the existence of a negative correlation between land-use change and carbon emissions.

Both markets and policy incentives drive differences in land-use patterns and consequent carbon emissions in different regions globally. Winkler et al. (2021) showed that forest areas in the global north are increasing while those in the global south are reducing. Also, global cropland is reducing in the global north and increasing in the south. Political reforestation initiatives in China and agricultural land relinquishment in the USA and Europe (Brya et al., 2018; Chen et al., 2019a, 2019b; Feng et al., 2016). Contrarily, market demand for global commodities and food has been the major driver of deforestation in the tropics, specifically through beef production, soybean and sugar cane production in Amazon, cocoa in Cote d'Ivoire, Ghana, Nigeria and Cameroon, oil palm in South East Asia (Austin et al., 2019; Holmes, 2002; Kharuk et al., 2013). A rapid increase in land-use change between 2000 and 2005 in the global south, principally in Sub-Saharan Africa, South America, and Southeast Asia, has been attributed to foreign agricultural investments through large-scale acquisitions (Arezki et al., 2015; Chen et al., 2017). However, after the global financial crisis, there was a slowdown in the land-use change in these countries.

This was exacerbated by a drop in global demand and concerns about the negative environmental impact of these large-scale land acquisitions and land-use changes (Henchiri et al., 2020; Mechiche-Alami et al., 2019). These explain the resulting impact of FDI on carbon emissions from LULUCF observed in this study and justify the negative and significant impact of high levels of FDI amongst low-income countries.

5.1.1 Economic growth, trade, and carbon emissions from land use, land-use change, and forestry (LULUCF)

Agriculture remains the primary source of livelihood and employment with reducing yields, increasing population, and global demand for food, increasing agricultural land is thus apparent (Piabuo et al., 2021). The Congo basin is dominant with forests; thus, agricultural expansion increases the forest loss rate (Brya et al., 2018; Chen et al., 2019a, 2019b; Feng et al., 2016). However, in Southeast Asia, at higher levels of growth, economic growth has a negative and significant impact on carbon emissions from LULUCF. This confirms the environmental Kuznets curve hypothesis, which stipulates that as countries' income rises, they tend to shift towards more R&D resulting in a technological shift, which improves their production process while also improving their environmental quality (Ali & Xialing, 2017; Javid & Sharif, 2016; Liu et al., 2019). Similar studies by Hitam and Borhan (2012) analysed the relationship between income, population pressure, inflow and outflow of FDI, and CO_2 emission in Malaysia using the Johansen cointegration method. The negative impact of FDI on environmental quality and the applicability of the EKC for the sample under study was revealed. This is principal because these countries have developed different technologies to enhance their production systems, reduce emissions, and achieve green growth plans. Governments in these countries have made huge commitments related to zero-deforestation for major tree commodities such as palm oil, enhancing ecosystem approach in the development and land-use planning with significant funding from governments and multilateral donors and partners (Nuntapotidech, 2012).

Our findings also find trade's positive and significant impact on carbon emissions in Congo basin countries. At the same time, there is a negative but not significant impact on high-income countries. This is consistent with Wang and Wang (2021), who find a negative and significant impact of trade openness on high-income and upper-middle-income countries and no impact on trade opening for lower-middle-income countries and a positive and significant impact for low-income countries. The key reason for this finding is the ability of high-income countries to put in place and respect high environmental standards in terms of trade, consumption, and even production systems. Low-income countries still have issues enforcing environmental regulation, land-use planning, and sustainable land management approaches.

Low-income and Congo basin countries face the dilemma of eradicating extreme poverty, the number one SDG, and fighting climate change. This conflicting situation is compounded by the fact that these countries depend primarily on subsistence agriculture to feed their growing population. Thus, agricultural expansion remains a reality at the detriment of forests. Hubacek et al. (2017) underscored that moving everyone to a modest rate of $2.97 purchasing power parity (PPP) increases mitigation efforts by 27%. This underlines that for country policies to be effective in attracting green investment and promoting green growth, there is a need for a certain level of development and governance system. This is further

supported by the findings of this study that underscores a positive and significant impact of governance effectiveness on carbon emissions in Congo basin countries.

5.1.2　Re-orienting from FDI to green FDI

For growth to be sustainable, these countries' economies must grow without jeopardising the environment for the future. Thus, this paper supports policymakers to rethink their growth path, reorientate towards green growth, and define and adopt a green FDI framework for their domestic economies. The ambition to adopt a green development pathway has been illustrated by high-income countries and other countries in Europe and Central Asia through developing green growth strategies for their countries for the next 25–30 years. These strategies capture green growth activities and plans for all sectors of the economy with a clear cost–benefit analysis for adopting these strategies (World Bank, 2022). Cost–benefit analysis for adopting green growth plans shows significant economic benefits that should be an eye-opener for other tropical countries to adopt. Also, these countries have adopted policies to scrutinise FDI inflow and only authorise green FDI; this has been done by defining and developing a framework to identify and classify FDI as green. Tree commodities are major export goods for tropical countries. Piabuo et al. (2022) underscored that the industrialisation of these economies through tree commodities can provide an alternative pathway to increased incomes and employment, thus reducing pressure on forests. Thus, regulating the institutional framework to promote agriculture intensification, industrialisation, and re-skilling towards high-value production sectors can limit land-use change and carbon emissions from LULUCF. This will also require ameliorating domestic, regional, and international trade by tropical countries.

6　Conclusion and policy implications

Agricultural land and global land-use patterns have changed dramatically over the last two decades, and these changes in the tropics have coincided with a significant increase in FDI towards these sectors. The scientific literature on the effects of FDI on carbon emissions can be summarised along three fronts; the first posits that FDI enhances carbon emissions and underscores that this is even severe in countries with weak governance systems or seeking growth at all costs. A second strand underscores that FDI permits technology transfer, thus enhancing climate-smart development pathways and reducing carbon emissions. The third strand underscores no impact of FDI on carbon emissions. This paper contributes to the current debate on FDI-environmental emission linkages by looking at the effect of FDI on carbon emissions from LULUCF. It adds to the literature by looking at how FDI affects carbon emissions from land use and forestry change. It also explores how current and higher levels of FDI and GDP affect carbon emissions from LULUCF.

　　Data from 30 tropical countries covering the period 1996–2019 were used for analysis, and a system panel dynamic panel data was employed. The sampled countries are divided into two units of analysis by tropical blocs: the Amazon, Congo basin, South East Asia, and Australasia, to capture regional differences in findings and how contextual settings explain the findings. The second unit of analysis is constructed on the hypothesis that the emissions levels due to FDI depend on the country's income levels; thus, the classification of countries into income levels by the World Bank is used to

segregate countries. The sample is divided into low-income, low-middle-income, upper-middle-income, and high-income. The findings reveal a U-shape structure of the impact of FDI on carbon emissions from LULUCF within the Congo basin and Amazon countries; at higher levels of FDI, emissions from LULUCF will increase.

Meanwhile, Australasia and Southeast Asian countries show an inverted U-shape impact; thus, at higher levels of FDI, there will be a negative and significant impact on carbon emissions from LULUCF. The findings by income levels revealed an inverted U-shape for low-income and high-income countries and a U-shape for upper-middle-income countries. However, the impact on lower-middle-income countries is not significant. Overall, for the whole sample, the impact depicts a U-shape.

These findings underscore the need to incorporate land-use and land-use change planning in the national agenda of Congo basin and high-income countries. This paper has underscored the relationship and impact of FDI on carbon emissions. It depicts that although FDI can be a viable vector of economic development, it can potentially have severe negative environmental impacts. Therefore, the orientation governments give to FDI determines the outcomes. This paper proposes that Congo basin, Amazon, and lower-middle and upper-middle-income countries should reorientate their growth strategies by developing green growth plans. This will entail better control of the type of FDI coming in and re-orienting towards green FDI, and a review of processing of foreign firms to ensure they are "green compliant". Also, these restrictions and re-directions should be coupled with a strong institutional setup, efficient governance system, and a conducive environment for investment. Potential benefits of adopting this growth pathway are not only environmental but significant economic benefits, which reduces the vulnerability of host countries to climate shocks and rural communities that depend on agriculture.

Data availability Data for this study were extracted from the World Bank Development Indicator database, World Governance indicators, and the FAO STAT that are publicly available and can be provided upon request.

Declarations

Conflict of interests The authors declare that they have no competing interests.

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