Climate shocks and charcoal production in Zambia

Protensia Hadunka, Rory Hardie, Anna Waller, and Torsten Figueiredo Walter

This brief explores findings from a study on the effects of climate shocks, specifically droughts, on charcoal production by smallholder farmers in Zambia.

- Zambia lost an estimated 324,000 hectares of natural forest in 2024, and charcoal production remains a significant driver of the country's forest degradation.
- Our study shows that droughts cause crop failure, pushing smallholder farmers to turn to charcoal production as an alternative source of income.
- To reduce charcoal-driven forest degradation in the aftermath of climate shocks, the Zambian government could complement existing charcoal bans with inclusive policies that:
    1. Reward forest conservation by piloting Payment for Ecosystem Services (PES) schemes to incentivise the protection of woodlands.
    2. Expand access to clean energy, such as LPG and sustainable biomass, through innovative financing mechanisms to reduce household reliance on charcoal.
    3. Support climate-resilient livelihoods, including through investments in early warning systems, smallholder irrigation systems, climate-smart agriculture and extension support.

The brief proceeds with the following structure: I. Policy Motivation, II. Research and Key Findings, and III. Policy Recommendations.

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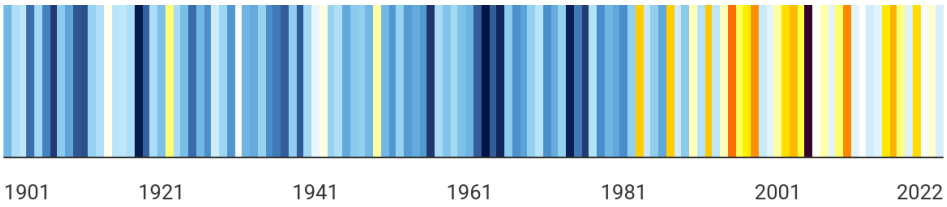
Policy Motivation

Climate change refers to long-term shifts in temperatures and weather patterns (United Nations, 2024). **Figure 1** illustrates the steady increase in Zambia's average annual temperature from 1901 to 2022.

FIGURE 1: Zambia's Annual Mean Surface Air Temperature (1901 – 2022)

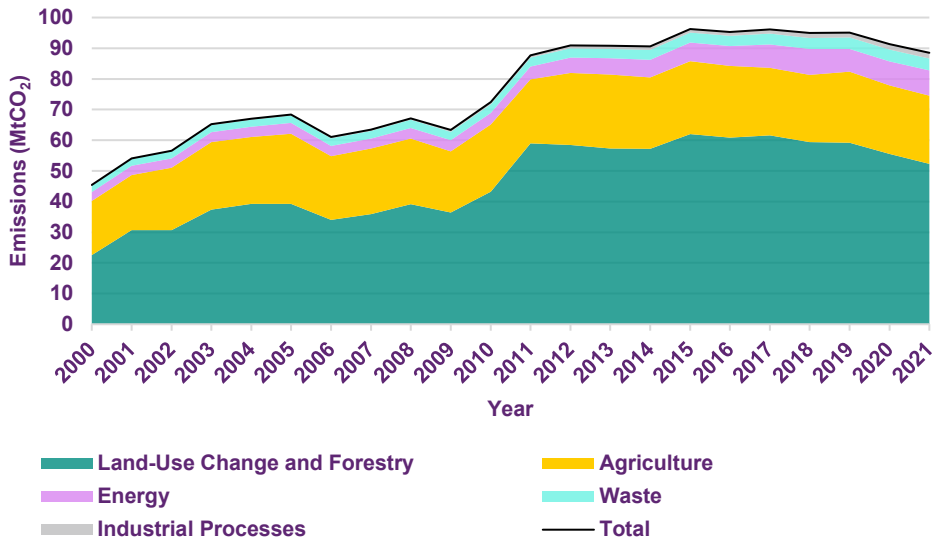


Data Source(s): World Bank (2025). Note: Blue indicates colder temperatures while red indicates warmer. As a point of comparison, the coldest year was 1963 at 20.92°C, and the warmest year was 2005 at 23.19°C.

- **Zambia's climate vulnerability** – developing countries are the most vulnerable to the negative impacts of rising temperatures (Burges et al., 2023). Climate change has intensified climate variability in Zambia, resulting in more frequent and intense shocks such as droughts and flash floods (World Bank, 2025). For example, during the 2023/2024 drought, Zambian farmers experienced the driest agricultural season in over forty years (OCHA, 2024).

- **Zambia's climate commitment** – the primary driver of climate change is the emission of greenhouse gases (GHGs). Therefore, as part of the global effort to mitigate the impacts of climate change, Zambia has committed to reduce GHG emissions by 47% from 2010 to 2030 *with* significant international support or 25% *without* significant international support (NDC Partnership, 2024). **Figure 2** shows Zambia's emissions breakdown.

FIGURE 2: Zambia's Emissions Breakdown (2000 – 2021)



Data Source(s): Climate Watch (2024).

As **Figure 2** illustrates, land-use change and forestry (LUCF) is the dominant source of Zambia's GHG emissions, accounting for 59% of total emissions in 2021. The main drivers are deforestation and forest degradation. Zambia lost an estimated 324,000 hectares of natural forest in 2024 (Global Forest Watch, 2025).

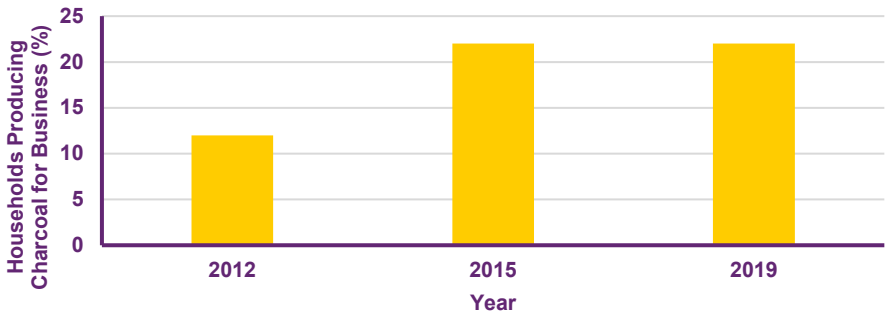
Rural households are aware of the rapidly declining forest cover. Approximately 63% of farmers report seeing a reduction in nearby forests (IAPRI and ZamStats, 2020). Yet many continue to rely on charcoal production, often as a coping strategy when crops fail.

Research indicates that charcoal-driven forest degradation now rivals deforestation from agricultural expansion as the primary cause of tree cover loss in Zambia (Sedano et al., 2022).

> **Charcoal production degrades an estimated 190,000 hectares of Zambia's forests each year (World Bank, 2019).**

Figure 3 shows the steady increase in the share of households engaged in charcoal production for business purposes. While most households already produce charcoal for their own use, the rise in commercial production highlights Zambia's growing economic dependence on charcoal production.

FIGURE 3: Household Charcoal Production for Business Purposes (2012 – 2019)



Data Source(s): Rural Agricultural Livelihoods Survey (RALS) 2012, 2015, and 2019.

The urgent need to tackle this issue is acknowledged in the government's 8th National Development Plan (8NDP), which strives to limit the unsustainable production and consumption of charcoal (GRZ, 2022). Addressing this issue requires policies which tackle the root causes of household vulnerability.

One potential cause of this charcoal burning is climate shocks. Since maize is both the main staple and a vital source of income, climate shocks that reduce harvests leave families with few alternatives. While it is very possible that these shocks force smallholder farmers to resort to charcoal production, research on this relationship is lacking.

Therefore, in this policy brief, we answer the question: ***What is the relationship between climate shocks and charcoal production in Zambia?***

Research and Key Findings

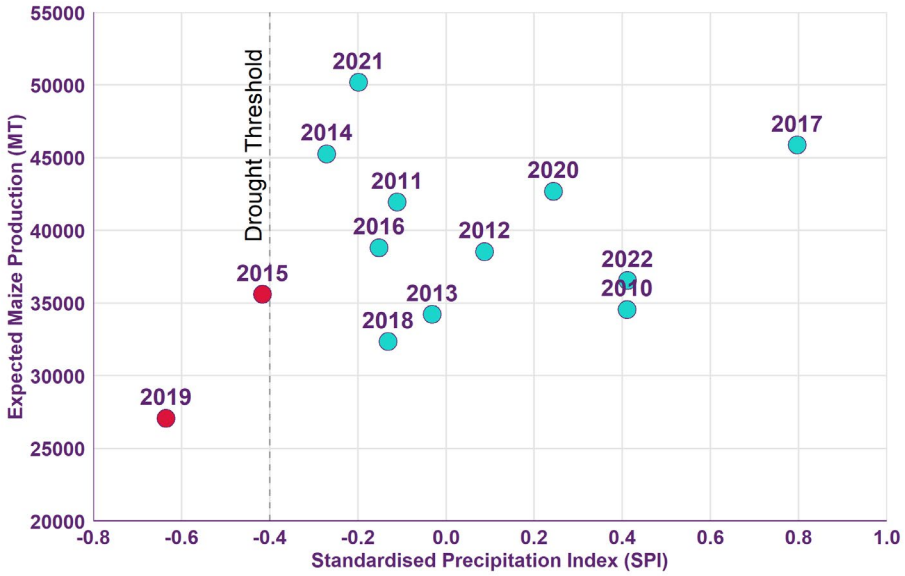
To explore the relationship between climate shocks and charcoal production, we focus on droughts in Zambia. The main data sources we use are the Household Income, Consumption and Production Survey (HICPS), Rural Agricultural Livelihoods Survey (RALS), Climate Hazards Group Infrared Precipitation with Stations (CHIRPS), Crop Forecast Survey (CFS), and Global Forest Change (GFC) dataset. These data sources are summarised in **Appendix 1**.

The key findings from the research are outlined below.

1. Reduced Crop Yield

The intuitive finding our research confirms is that droughts in Zambia cause significant reductions in crop yield and agricultural productivity. **Figure 4** displays annual expected maize production, in megatons (MT), against the Standardised Precipitation Index (SPI)[1]. (See the event study diagram in **Appendix 3** with a detailed explanation).

FIGURE 4: Droughts and Expected Maize Production



Data Source(s): Climate Hazards Group Infrared Precipitation with Stations (CHIRPS) and Crop Forecast Survey (CFS). SPI below -0.4 indicates a drought year.

Figure 4 shows the general correlation between rainfall and maize production. Evidently, droughts are linked to crop failure and an aggregate reduction in the output of Zambian farmers. For example, expected maize production in the 2019 drought year was 36.57% lower compared with the following non-drought year, 2020.

[1] The SPI measures the standard deviation that observed precipitation deviates from the long-term mean.

Of course, it should be noted that there are other shocks which impact crop production. For example, the low production in 2018 shown in **Figure 4** can be largely attributed to a pest outbreak, specifically an infestation of armyworms, which attacked maize crops (AGCO Future Farm, n.d.).

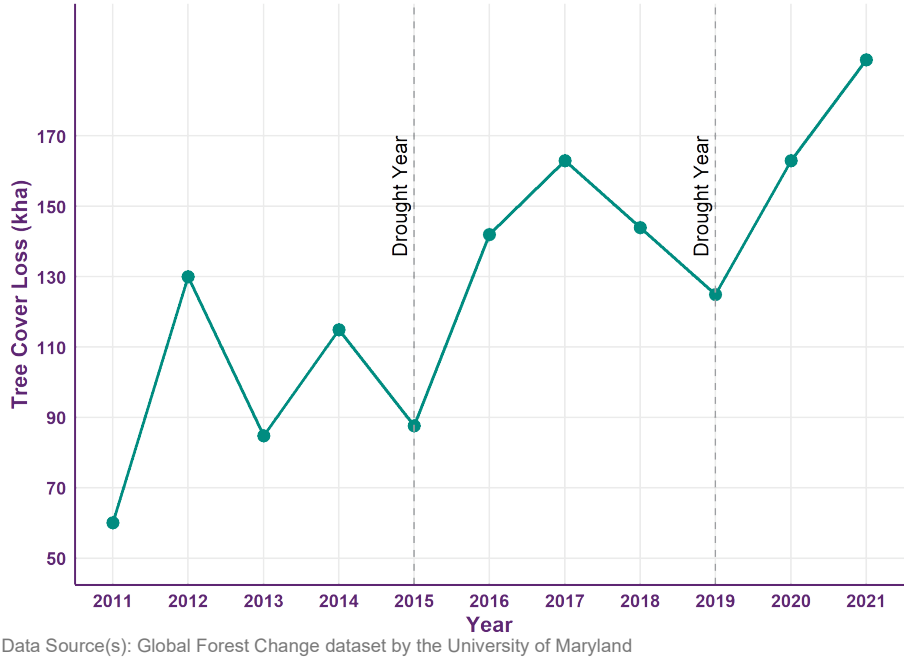
While multiple factors influence correlations, causal analysis looking at individual households over time in the HICPS data, in combination with the CHIRPS precipitation data, confirms the relationship between droughts and yield. We classify a household as experiencing a drought if its Standardised Precipitation Index (SPI) falls below negative 0.4:

- **Drought causes crop failure** – we find that drought exposure causes a statistically significant 36% reduction in maize yields.[2] The point estimate graph can be found in **Appendix 2**.

2. Increased Charcoal Production

The second finding of our study is that droughts increase charcoal production among smallholder farmers. **Figure 5** shows the correlation between drought years and tree cover loss in Zambia (See the event study diagram in **Appendix 3** with a detailed explanation).

FIGURE 5: Droughts and Tree Cover Loss



Data Source(s): Global Forest Change dataset by the University of Maryland

As **Figure 5** illustrates, in the years following the droughts of 2015 and 2019, the rate of tree cover loss increased in Zambia. The reason the increase in tree cover

[2] The analysis is based on a panel regression framework with standard difference in differences with fixed effects, where maize yield serves as the outcome variable. The primary regressor of interest is a binary drought indicator, and the model includes a full set of controls for input use consistent with the structure of a standard agricultural production function. Note: We acknowledge that using a binary drought indicator may mask variation within non-drought years, potentially biasing estimates if the comparison group includes unusually good or bad rainfall years. However, in our case, the non-drought group displays substantial variation, which helps balance extremes and reduces the risk of systematic bias.

loss occurs *after* the drought (not during) is likely because of the structure of the agricultural season.

Farmers typically begin planting activities at the end of November (Vorlaufer et al., 2017). Maize, the staple crop in many regions, is usually harvested by July (Adnan et al., 2017).

When harvests are poor, income pressures intensify after the harvest, in September. The shift to charcoal production often begins late in the year when the shock occurs and extends into the following year, with increased intensity during the lean season as households await the next harvest. As a result, much of the increase in tree cover loss due to charcoal production becomes visible in the year following the drought.

When we look at satellite data on the level of tree cover loss within a 5 km radius of smallholder farmers' households, we find that:

- **Droughts cause tree cover loss** – droughts increase tree cover loss by 51% around affected households.[3] The point estimate graph can be found in **Appendix 2**.
- **Droughts increase the likelihood of charcoal production –** droughts increase a household's likelihood of participating in charcoal production by 3 percentage points from a baseline participation rate of 20%. The point estimate graph can be found in **Appendix 2**.
- **Charcoal production drives tree cover loss** – in drought years, an estimated 40% of tree loss occurs near charcoal-producing households and only 11% is linked to cropland expansion or extra firewood collection, implying charcoal production is likely a main source of tree cover loss after droughts.

3. Characteristics of Charcoal Producers

To fully understand the drivers of farmers transitioning to charcoal production, it is critical to breakdown the characteristics of those engaged in charcoal production. **Table 1** shows the characteristics of charcoal producing farmers against those who do not.

- **Charcoal production is a coping strategy** – **Table 1** suggests that charcoal production could be a survival strategy for poorer, less educated, and less productive farmers. For example, on average, they

[3] We estimate the causal effect of drought exposure on deforestation using rainfall anomalies derived from the CHIRPS dataset. The identification strategy is based on the premise that droughts reduce agricultural income, prompting households to turn to charcoal production as an alternative source of livelihood. We employ a standard difference-in-differences (DiD) approach, leveraging variation in drought exposure across time and space. Deforestation outcomes are measured using satellite-based forest loss data from the Global Forest Change dataset. The analysis includes household and year fixed effects to control for time-invariant unobserved heterogeneity and common temporal shocks.

produce 50.7% less maize, have 66.6% lower asset value, and 2.8% less years of education. In addition, they are on average 4.2 km closer to the market which likely facilitates charcoal sales.

TABLE 1: Characteristics of Charcoal Producing Households

Attribute	Producing Charcoal	Not Producing Charcoal
Age of Household Head (Years)	41.72	45.79
Male Household Head (%)	93	83
Assets Value (ZMW)	5,854	17,502
Total Maize Production (KG)	1,845	3,744
Education of Household Head (Years)	6.14	6.32
Distance to Market (KM)	7.18	11.45

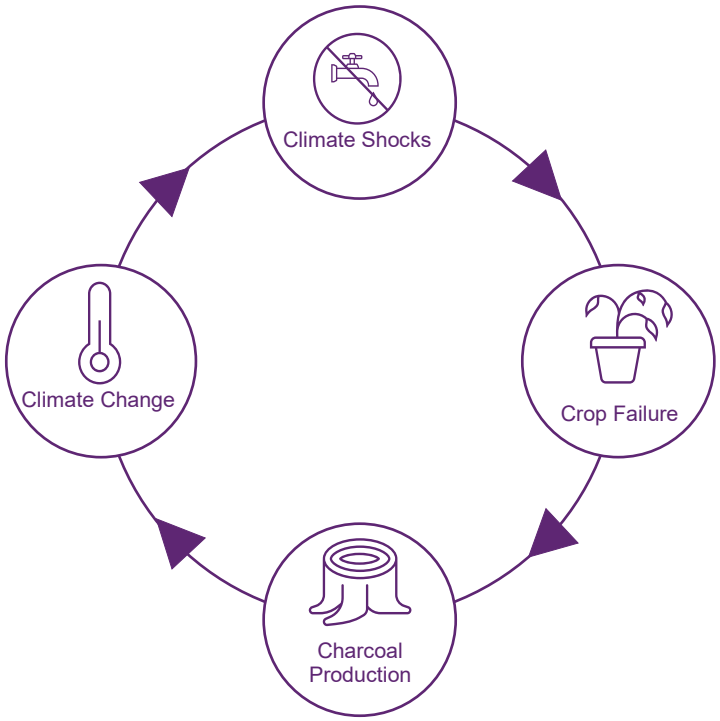
Data Source(s): Rural Agricultural Livelihoods Survey (RALS).

All these differences in characteristics, which are statistically significant, suggest that charcoal production may be a last-resort income source when farmers face climate shocks.

4. Climate Change Cycle

Our findings suggest that there is a self-reinforcing cycle between climate change, climate shocks, crop failure, and charcoal production.

FIGURE 6: Climate Change Cycle



As **Figure 6** illustrates, climate change leads to increased climate shocks (droughts, floods, and pest outbreaks). This causes crop failures, reducing farmers' incomes and forcing them to seek alternative livelihoods. In response,

many turn to charcoal production, relying on forest degradation to meet their financial needs.

This cycle accelerates tree cover loss, reducing the ability of trees to absorb carbon dioxide while also releasing GHGs during the charcoal-making process. The resulting increase in atmospheric GHGs intensifies climate change, leading to rising temperatures and more extreme weather conditions, which further disrupt agriculture and perpetuate the cycle.

There is an additional worrying element to this cycle. The shift to charcoal burning occurs during the off-season, when farmers would typically engage in land preparation for the next agricultural cycle. Since they are occupied with charcoal production instead, they delay land preparation, reducing agricultural productivity in subsequent seasons. With lower yields and incomes in the following season, they again turn to charcoal production to compensate for these losses, perpetuating a self-reinforcing cycle of tree cover loss, lower agricultural output, and climate deterioration.

Policy Recommendations

Charcoal production is one of the primary drivers of tree cover loss in Zambia (Sedano et al., 2022; Richardson et al., 2021; Vinya et al., 2011), and our study shows that this is exacerbated by climate shocks. To break the vicious cycle, policy innovations must target both the supply and demand side of charcoal production in Zambia.

BOX 1 – Zambia's Existing Charcoal Policy

The Community Forest Regulations of 2018 and the Forest Act of 2015 provide the legal framework for the regulation of charcoal production, outlining the licencing requirements for charcoal production and the roles of community forest management groups (GRZ, 2015; Ngoma et al. 2020). In 2024, in line with these regulations, the government imposed a ban on the issuance of new charcoal production permits in three 'hotspot' districts – Itezhi-Tezhi, Mumbwa, and Shibuyunji (Lusaka Times, 2024).

While bans may reduce charcoal production in the short run, they fail to address the root causes. Bans are only effective when they are complemented by policies that create space for alternative livelihoods and energy sources. On their own, bans will likely punish the poorest households, leaving them without a source of income or energy. And, while cash transfers like the Drought Emergency Social Cash Transfer might plug the income shortfall for smallholder farmers after a drought, they do not incentivise farmers to reduce charcoal production.

Below we outline policy recommendations which seek to address the root causes of charcoal burning, especially in the context of climate shocks.

1. Reward forest conservation, for example, use Payment for Ecosystem Services (PES) schemes to incentivise the protection of woodlands.

As discussed in the Policy Motivation, charcoal burning has significant environmental costs – particularly in terms of climate change – which are not solely experienced by the charcoal burners themselves. The costs associated with climate change are experienced at the local, national and international level.

- **Leverage International Finance** – the government of Zambia can leverage existing international climate and development finance frameworks to incentivise smallholder farmers to conserve rather than burn during droughts. For example, there is the UNFCCC's Reducing Emissions from Deforestation and forest Degradation (REDD+) framework. This climate finance mechanism rewards developing countries for keeping their forests intact and provides results-based payments.

- **Pilot PES Programs** – there is room to explore the implementation of schemes such as Payment for Ecosystem Services (PES). PES schemes work by paying individual farmers, groups of farmers, or communities to not engage in charcoal burning. Research in Uganda found that in villages where PES are implemented tree cover only declined by 4.2%, whereas it declined by 9.1% in villages without PES (Jayachandran et al., 2017). The specific payment can be calculated using existing methodologies[4] which determine the total value of the specific ecosystem service. These PES schemes could target communities who are on the margin of forests and vulnerable to climate shocks. They could also be embedded within the existing Community Forest Management (CFM) regulations (Ngoma et al., 2020).

- **Invest in Data Infrastructure** – for such PES schemes to be effective from both a financing and implementation perspective, there has to be adequate and granular monitoring of Zambia's forests. As part of the REDD+ initiative, Zambia is strengthening its National Forest Monitoring System (NFMS) using remote sensing (e.g., satellite or drone data) and ground-based data. Investing in this data infrastructure is critical to effective policies which incentivise the reduction in charcoal burning.

One issue that should be addressed in regard to jurisdictional based approaches, such as REDD+, is the benefit sharing mechanisms. These

[4] For example, there are market-based approaches which use existing prices than can be linked directly or indirectly to non-priced goods like calculating the opportunity cost of not deforesting an area by looking at the value in terms of charcoal sales. Equally, there are demand-curve approaches which look at how much beneficiaries value the ecosystem service – i.e., their willingness to pay (FAO 2022)

approaches have been criticized for not effectively engaging the local communities to co-develop benefit sharing mechanisms that are mutually beneficial to the communities and the projects. There is a problem of information asymmetry where the local community leadership are not privy to the real benefits generated and the price of the carbon they generate. This creates mistrust and discourages communities from conserving forests. The recently enacted Green Economy and Climate Change Act No. 18 of 2024 provides for processes to address some of these concerns. However, there is a need for enforcement without crowding out private sector investments in carbon markets.

2. Expand access to clean energy, such as LPG, biogas and sustainable biomass, to reduce household reliance on charcoal.

The high demand for charcoal as a source of energy in Zambia drives production by smallholder farmers. According to Zambia's National Energy Access Survey (NEAS), in 2023, 57.6% of households were using charcoal and 98.8% of these households were using it for cooking. In contrast, only 1% of households in 2023 were using Liquefied Petroleum Gas (LPG) – a cleaner energy source which does not require deforestation.

There have been calls to make these clean energy solutions more accessible by implementing policies such as:

- **Invest in LPG Production** – subsidies to Small and Medium Enterprises (SMEs) who engage in the provision of LPG (Chisanga et al., 2022). Equally, investment in the necessary infrastructure like import terminals, storage facilities, and distribution networks can support the supply of LPG in Zambia (Besa and Chiwele, 2023).

- **Innovative Financing for Low-income LPG Purchases** – other innovations in the LPG sector, include providing subsidies for LPG stove purchases and the adoption of technology-enabled pay-as-you-go (PAYG) solutions, which could potentially make such clean energy solutions more attractive than charcoal (CCA, 2021). IGC work in Tanzania found that LPG provision via subsidies reduces charcoal consumption by 32% (Alem et al., 2017).

- **Other Charcoal Alternatives** – there are also policy options to explore in the biogas and sustainable biomass space. In 2023, only 0.05% of Zambian households were using biogas and sustainable biomass solutions, such as pellet or briquette stoves, remain largely unscaled. These figures showcase the room for growth and enabling policies which integrate fiscal incentives, regulatory support, and consumer

awareness campaigns to make cleaner fuels a desirable substitute for charcoal.

3. Support climate-resilient livelihoods, including through investments in early warning systems, climate-smart agriculture and extension support.

IGC's work in Zambia highlights the importance of incentivising climate-smart agricultural techniques (Teschemacher et al., 2024). It is critical that such policies not only target the adoption of these techniques, but also, given the high rates of dis-adoption, support the sustained use of these techniques.

- **Improve Agricultural Support Services** – improving agricultural extension services is essential to reducing farmers' reliance on charcoal production, particularly during climate shocks. When farmers lack timely guidance or support, they may be more vulnerable to crop failure and turn to charcoal as an emergency income source. Expanding the number of trained extension officers, easing their administrative burden, and equipping them with tools like motorbikes would enable more consistent and tailored support to remote farming communities. Embedding farmers more actively into the learning process—through participatory methods and improved communication—can also ensure that sustainable practices take hold.

- **Improve Agricultural Information Services** – access to accurate and localized climate information can help farmers make better planting and harvesting decisions, reducing the risk of total crop failure and the need to fall back on charcoal burning. Information such as the timing of rains, seasonal forecasts, and extreme weather warnings should be delivered through accessible channels—like radio, SMS, or community meetings—so that even resource-poor farmers can respond effectively. Evidence from Ethiopia and elsewhere shows that climate-informed agriculture boosts productivity and resilience, providing a more stable alternative to charcoal as a drought-time coping strategy.

- **Upscale Smallholder Irrigation** – investments in irrigation infrastructure for smallholder farmers can increase their resilience to climate shocks. Most irrigation services currently target large-scale commercial farming, and more focus is needed on smallholder farmers (African Water Facility, 2016).

- **Increase Access to Alternative Livelihoods** – to reduce dependence on charcoal and other forest resources, communities need access to income sources that do not harm the environment. Programs that provide training and support for small businesses in areas like poultry

farming, beekeeping, and conservation agriculture can help families earn a stable income. These efforts should be linked with incentives for protecting forests, ensuring that both people and nature benefit. Investing in alternative livelihoods is a practical way to improve rural incomes while reducing tree cover loss.

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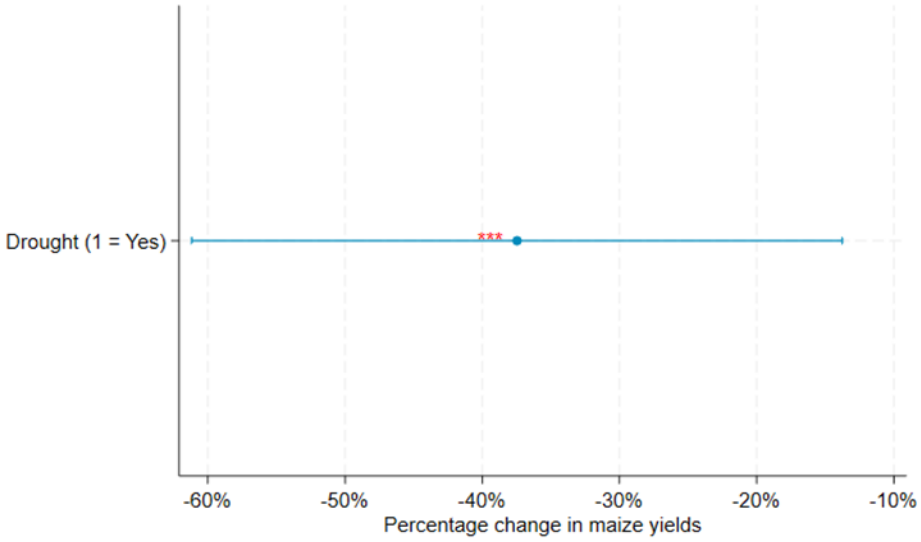
Appendix 1 – Data Sources Summary

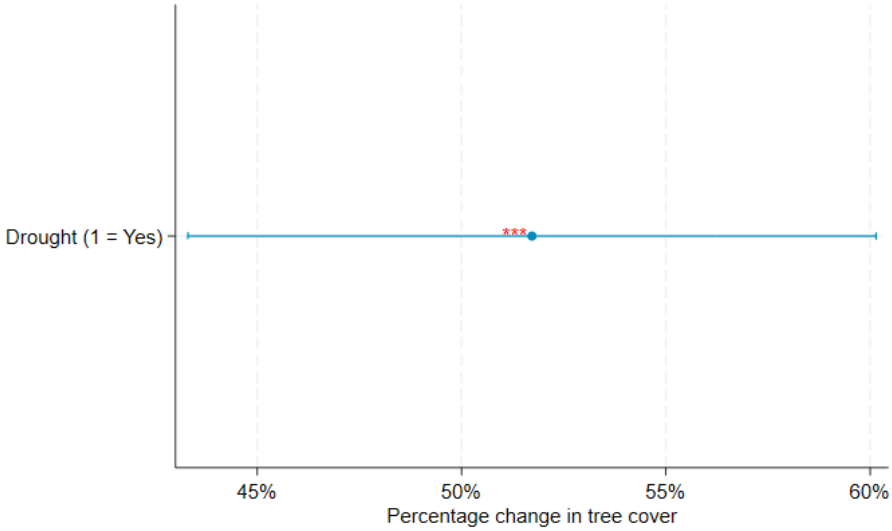
Name	Description	Years
Household Income, Consumption and Production Survey (HICPS)	Household data on socioeconomic characteristics, agricultural production, charcoal/firewood activities, and income/expenditure for the same 1,200 smallholder farmers.	2016 – 2019
Rural Agricultural Livelihoods Survey (RALS)	Household data on agriculture, demographics, income, assets, and agricultural production practices for approximately 8,800 smallholder farmers.	2012, 2015, & 2019
Climate Hazards Group Infrared Precipitation with Stations (CHIRPS)	Gridded satellite-based precipitation data at 0.05° resolution, capturing monthly rainfall estimates across Zambia.	1981 – 2024
Crop Forecast Survey (CFS)	Household survey data which generates district-level crop yield data, and production by crop type.	2002 – 2022
Global Forest Change (GFC)	Based on Landsat imagery, provides 30-meter resolution forest cover data offering annual estimates of tree loss/gain since 2000.	2001 – 2021

Appendix 2 – Point Estimates

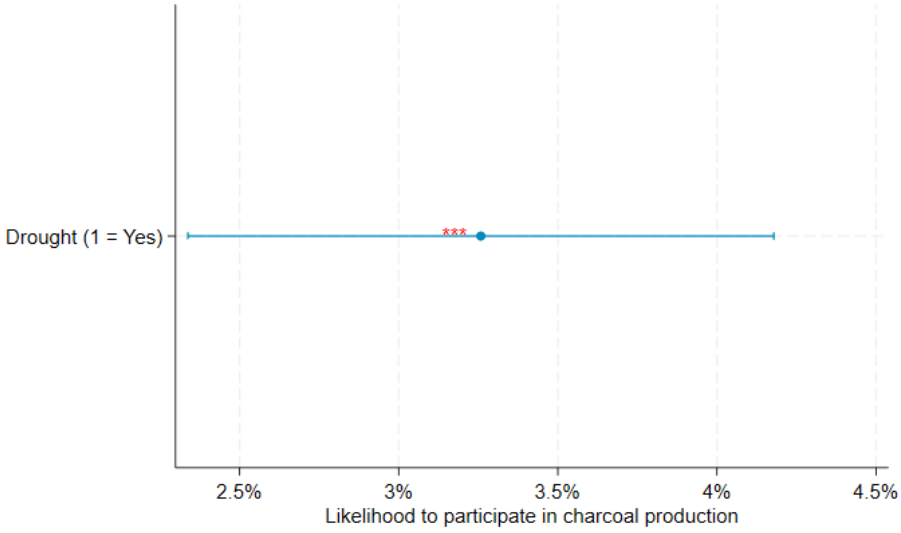
2.1. Droughts & Maize Yields



2.2. Droughts & Tree Cover Loss



2.3. Droughts & Charcoal Participation

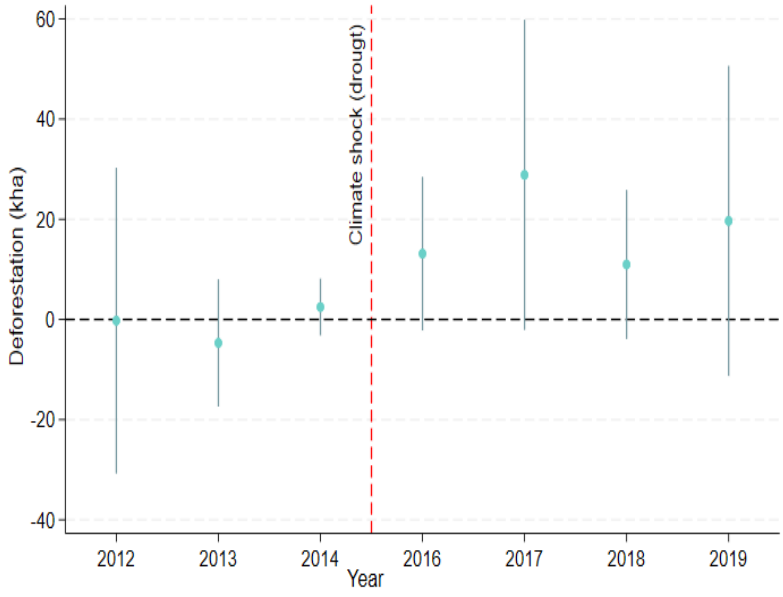


Appendix 3 – Event Study Graphs

Droughts in Zambia create a clear chain reaction that affects both farming and forests. As shown in the first figure, deforestation remained relatively steady before the 2015 drought, with no meaningful differences across districts. After the drought, however, deforestation rises sharply, especially in 2016 and 2017, reflecting how households respond once their harvests fail. The second figure shows the underlying cause: maize yields were stable for several years but dropped immediately after the drought and stayed low, indicating a major loss of farm income. With few alternatives and charcoal

prices remaining largely unchanged, households turn to charcoal production as a coping strategy rather than as a response to better market opportunities. This shift increases pressure on nearby forests, contributing to the rise in tree loss after the drought. Together, the evidence shows that drought reduces agricultural output, pushes households into charcoal production, and leads to higher rates of deforestation, highlighting how climate shocks can create cascading livelihood and environmental impacts.

3.1. Droughts & Tree Cover Loss



3.2. Droughts & Maize Yield