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Agribusiness, health, and gender: The case of pesticide use in the Colombian cut-flower industry

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Abstract

Pesticide use in the cut-flower business of Colombia threatens both planetary and human health. More than half of the workers in the cut-flower industry are female, which implies that women face disproportionately more risks associated with these toxic chemicals. Additionally, through responsibilities for household tasks, women are also indirectly more exposed to pesticides that have leaked into the soil or water, showing the intricated link between environmental and human health. This study examines the causal relationship between pesticide use in the cut-flower industry and health outcomes for women in the two departments of Colombia that are responsible for 99% of cut-flower production, Antioquia and Cundinamarca. The results show that cut-flower farm activity is associated with more frequent medical visits for women with concerns related to pregnancy, childbirth, and the puerperium. The paper further links these outcomes to the relationships and incentives within the current agricultural and economic system, by drawing on insights from the theory of Ecologically Unequal Exchange.

Keywords: Pesticide use, cut-flower business, women’s health, Ecologically Unequal Exchange

Table of contents

1. Introduction

Partly due to the use of agrochemicals, global yields in agriculture have more than doubled in the last 50 years (Robinson, 2018; Carvalho, 2017). This increase in productivity paired with trade liberalizations has allowed the agricultural system to support the global rise in population, greatly reducing the incidence of famine deaths and malnourishment (OWID, 2017). But besides being a source to meet basic needs, modern agriculture is also a source of social and environmental issues. The agricultural sector is a large contributor to human-induced climate change, responsible for 15% of global emissions as well as eutrophication, soil degradation, and biodiversity loss (The Lancet, 2019). When examining international supply chains, regions that are large exporters of agricultural goods carry much of the environmental burden associated with consumption in the Global North, and this often disproportionately impacts Global South nations (Hickel et al., 2021). [1] This unequal distribution of costs and benefits is especially evident when examining pesticide use in Colombia's cut-flower business.

Over the last 50 years, Colombia has become the second largest exporter of cut-flowers in the world, exporting more than 95% of the flowers it produces to Global North markets. The impressive growth of the sector can in part be ascribed to the use of pesticides, some of which are illegal elsewhere. The EU and the US have banned the use of certain harmful pesticides from being used for or imported through food products, it has not banned those same pesticides for the importing of non-food products (Daam et al., 2019). Exporting nations in the Global South often lack similar regulations and are therefore exposed to a large share of the environmental and health risks associated with pesticides. Furthermore, all large importers of cut-flowers are situated in the Global North, meaning these countries are effectively outsourcing the environmental and health burden associated with their cut-flower consumption. This burden is also not shared evenly within producing countries. Within the cut-flower business, more than half of the workers in the cut-flower business are women, meaning women are disproportionately in contact with these harmful chemicals. Despite this, pesticide exposure and related health impacts for women in the Global South are understudied and underestimated in the literature (London et al., 2013; Asmare et al., 2022).

[1] In this paper, the terms Global North, high-income, and wealthier countries are used interchangeably to refer to the group of OECD countries, and Global South, low-income, and poorer countries refers to all others. The South is of course not a homogenous group, and Colombia may fall on the border of some of these binary classifications, but this does not impact the outcome of this thesis.

To combine these insights at the intersection of agribusiness, the environment, health, and gender, this paper aims to answer the question: What is the impact of pesticide use in the cut-flower business on women's health in Colombia?

To answer this question, three sub-questions have been identified:

1. What are the risks of exposure to pesticides for the human body and the environment, and how do these risks disproportionately affect women?
2. Do women in regions with a high use of pesticides have more reproductive health issues?
3. How is modern agriculture linked to the use of pesticides, and how do unequal trade relationships incentivize agricultural practices?

To answer these questions, this paper will take an interdisciplinary approach, combining insights from environmental and health sciences, economics, and philosophy. Based on environmental and health sciences literature, Chapter 1 starts with a brief overview of the flower sector in Colombia, and includes a description of the disproportionate risks that women in the cut-flower business face. Following these findings, Chapter 2 quantifies the relationship between pesticide use and reproductive health outcomes for women by performing a regression analysis. In Chapter 3, the results from the from the regression model will be analyzed in broader perspective. This is chapter draws economic insights and is further divided in two parts. First, neoclassical theories and assumptions on trade and agriculture are explained and challenged by the theory of Ecologically Unequal Exchange. This theory argues that, facilitated by international trade, unequal power relationships result in asymmetric flows of natural resources between the Global North and the Global South. Second, insights from these economic theories are applied to understand the relationships and incentives underlying the cut-flower industry of Colombia. The aim of the analysis is to illustrate that pesticide use is not only the cause of adverse reproductive health outcomes for women, but also the symptom of an agricultural system where efficiency and growth are prioritized over health and wellbeing.

Lastly, to complement the shortcomings of a purely economic perspective, the discussion draws on philosophical insights. This critical normative angle allows for a deeper understanding of the plight of women and opens up the question of who has what responsibilities to fight injustices within the cut-flower business.

2. Colombia’s cut-flower industry, pesticides, and the role of women.

Colombia is the second largest exporter of cut-flowers in the world, after the Netherlands. Trade is of key importance to the sector as 95% of the flowers produced in Colombia are exported, supplying 16% of the world market, with a total estimated value of 1.7 billion US dollars (OEC World, 2021). Around 78% of Colombian exports go to the United States, where Colombia is the number one supplier of cut-flowers. Other important destinations are Japan, Canada, and the Netherlands, each importing 6% of Colombian production. Colombia is the leading exporter of carnation flowers, big roses, and orchids (Faust & Dole, 2021). Within Colombia, 99% of all cut-flower farms are in located two departments, Antioquia, producing 32% and Cundinamarca, producing 66% of all flowers (IcA, 2022). In 2021, the country produced more than 240 tonnes of flowers, using around 8.6 thousand hectares of land. According to Ascolflores, the Association of Cut-flower Exporters in Colombia, the cut-flower industry consists of a large number of unskilled labourers with an estimated 95,000 people working in direct jobs of handling flowers, and 80,000 people working indirect jobs such as packaging and transportation. Automation is still lacking in the industry, and thus the production, harvesting and processing tasks are still performed by manual labourers (DANE, z.d.). As a result, labour is the single largest expense for cut-flower growers (Faust & Dole, 2021). Common cost-reducing strategies within the industry are therefore to hire cheap, mostly female labourers, and to use pesticides to prevent the spread of pests and plant disease.

The use of pesticide is problematic because it poses a risk to human and environmental health. Pesticides leak into the environment, contaminating the water, soil, and air. This has caused mass killings of insects and animals such as bees, birds, and fish, severely disrupting local ecosystems and contributing to global biodiversity loss (Pereira et al., 2021). Through this impact on biodiversity, pesticides present one of the key threats to global food security (The Lancet, 2019; Henser, 2023). Pesticides also present a direct risk to human health because of their toxicity. Medical literature finds that exposure to pesticides either directly through the air, or indirectly through contaminated food or water, leads to respiratory, dermatological, and neurological issues (Akhtar et al., 2021; Asmare et al., 2022). Due to these potential health consequences, the EU and the US have banned the use of certain pesticides for the production and importing of food products. Yet for the importing of non-food products such as cut-flowers, there are no set limits. As a result, flower producers in the Global South often use a high amount of pesticides that are illegal in the Global North, to achieve lower costs and higher yields necessary to compete in the global market (Daam et al., 2019; Pereira et al., 2021).

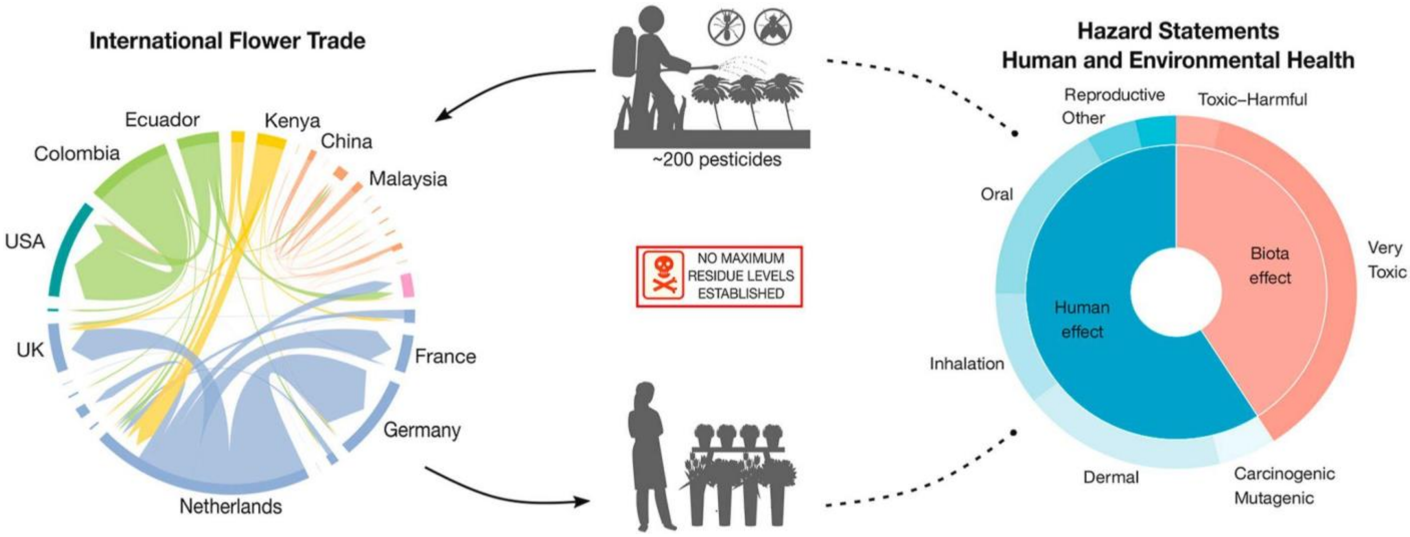

Figure 1 – The relationship between trade in cut-flowers and environmental and human health outcomes. Source: Pereira et al, 2021.

Figure 1 graphically illustrates the interconnectedness between trade, pesticides, and human and environmental health in the global cut-flower business. As *Figure 1* highlights, all major importers of cut-flowers are situated in the Global North. These importing nations have no maximum residue limits for pesticides when it comes to cut-flowers. Therefore, due to the lack of regulation, the consumption of cut-flowers in the Global North, produced in the Global South, is associated with environmental and human health impacts. In the case of Colombia specifically, this is expected to disproportionately impact women.

Ascolflores reports that within the industry, 60% of the workers are women (Ascolflores, 2019). Other sources indicate numbers as high as 80% (Patel-Campillo, 2012), representing around 25% of all female rural labour in Colombia (Fernandez, 2015). Women in the cut-flower industry disproportionately face risks from pesticide-use due to two factors. First, women face disproportionate risks due to biological factors. Their relatively higher levels of adipose tissue and hormonal changes increase susceptibility to pesticides causing acute/chronic diseases (London et al., 2013).

Second, women in the Global South are increasingly exposed to and affected by pesticides through their increasing participation in the agricultural labour force (Asmare et al., 2022). Agricultural workers are generally a vulnerable group due to the combination of socioeconomic risk factors together with the exposure to pesticides inherent to their work, where they are often lack sufficient personal protective equipment, increasing their risk of serious illness (Curl et al., 2020). Through their work in agriculture, women face risks due to direct contact, as applicators of pesticides, and indirect contact, by being exposed to contaminated soil or clothing. On top of that, non-occupational exposure can happen through exposure to contaminated food and water, as women are still mainly responsible for household tasks.

The improved labour market participation of women, through its impact on poverty, is generally associated with reduced gender inequality and women empowerment (Duflo, 2012, p. 1054). Within the agricultural industry move specifically, Anderson finds that empowering women, giving them more control over their own labour and mobility, is associated with improved nutrition and educational attainment. Nevertheless, accounts of working conditions for female labourers in the cut-flower industry highlight a different side. Patel-Campillo (2012) finds that within the industry, women generally work lower-end, lower-paid jobs, and have more insecure employment contracts. Women are therefore disproportionately affected by cost-reducing strategies to maintain Colombia's competitiveness in the global cut-flower market, an issue that will be returned to in the analysis.

In sum, the cut-flower business in Colombia is associated with the use of pesticides which threaten environmental and human health. As in Colombia the workers in the industry are mainly women, and women face additional risks when exposed to pesticides, the following section will aim to quantify one aspect of the impact of pesticide use in the cut-flower business on women's health.

3. Regression Model

Data Collection

To test whether there is a significant positive relationship between pesticide use in the cut-flower business and adverse health outcomes for women in Colombia, this study uses healthcare data from the 2019 records of the Individual Records of Provision of Health Services (*Individual Records of Provision of Health Services*, RIPS) aggregated at the municipal level. The Colombian healthcare system is regulated by the Ministry of Health (MoH) and healthcare services are delivered by both private and public providers known as *Instituciones Prestadoras de Servicios,* or IPS. The IPS reports Routinely Collected Health Data (RCHD) such as RIPS back to the MoH, which then makes the anonymized records publicly available. RCHD is increasingly important in medical research and is therefore the appropriate dataset for this research (Benchimol et al., 2015).

The RIPS dataset consists of nearly 102 million registered medical visits for Colombia in total, but this study will only look at data for the departments of Antioquia and Cundinamarca, where 99% of flower production takes place. The data was collected for the years 2019, 2020 and 2021, but only the data for 2019 is used as the COVID-19 pandemic likely drastically inflated the number of medical visits. The data is classified among four types of medical attention: consultation, medical treatment, hospitalization, and emergencies. All four types are included in the scope of this analysis. Furthermore, the IPS classify each type of attention according to the type of diagnosis. The type of diagnosis relevant for this study is type O (pregnancy, childbirth, and the puerperium). This diagnosis is chosen because the data is aggregated to the municipal level, without information on gender and number of visits, and therefore a gender-specific diagnosis is chosen. After narrowing down the data for the year 2019, the municipalities Antioquia and Cundinamarca, and for type O diagnoses, approximately 8.4 million observations across 240 municipalities remained, see Appendix A for a further specification of this process.

All but one of the further datasets come from the 2018 Population Census of Colombia, reported by the National Administrative Department of Statistics (DANE). These include the Multidimensional Poverty Index, Population, and Access to Healthcare. Lastly, the data on hectares of flower farms per municipality come from a 2010 report of the Colombian

Agricultural Institute (IcA), and the current number of hectares is extrapolated based on data from the IcA and trade statistics from OEC World.

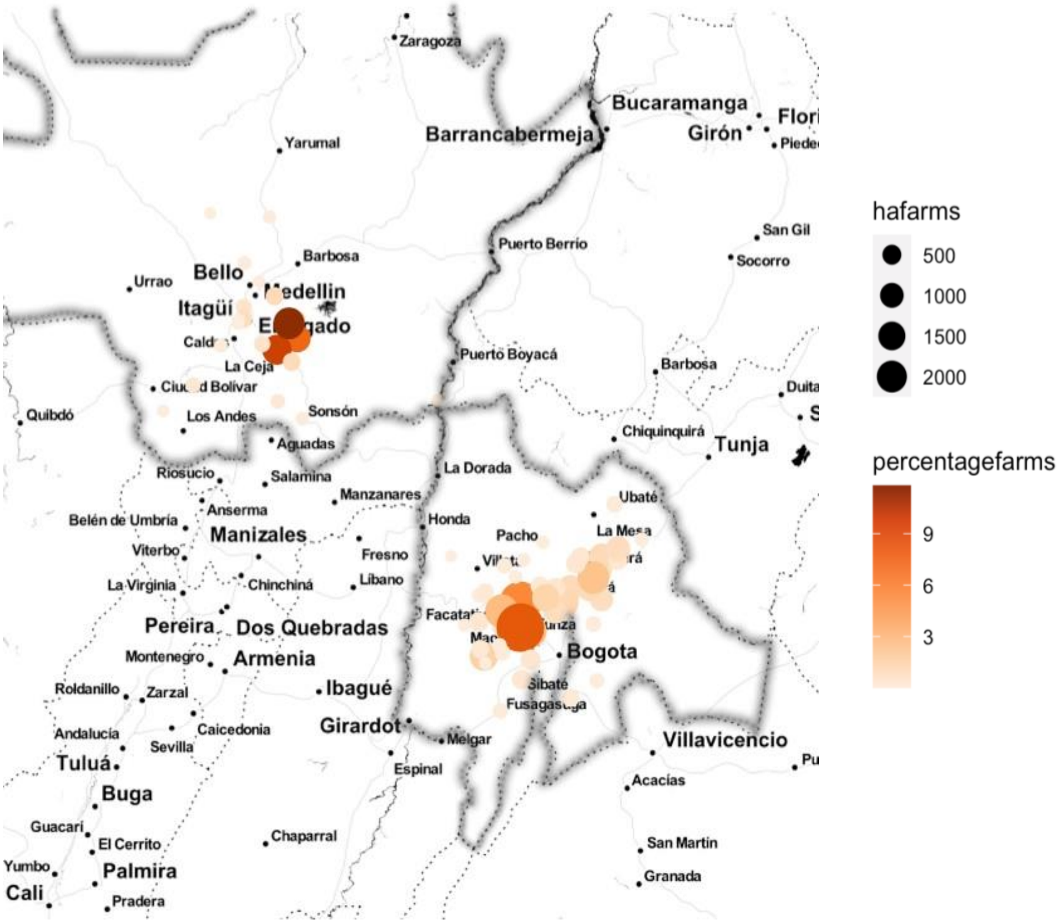

Figure 2 – Geographical distribution, size and share of flower producing municipalities.

Out of 240 municipalities, only 65 municipalities have some level of cut-flower farm activity. *Figure 2* shows the geographical distribution of the municipalities growing flowers, including the absolute number of hectares, and the share of flower farm hectares out of the total land in the municipality.

There are three main limitations arising from the choice of data. First being that the dependent variable is chosen to be gender specific, because information on gender or number of visits per individual are missing. Because of this, it is not possible to compare results for men and women. Second, the use of pesticides is proxied by looking at hectares of flower farms, but this data is only available for the year 2010. More recent records or reports on the exact number of pesticides used could yield more precise results. Lastly, RIPS are reported by formal medical institutions, individuals seeking alternative medical treatment or self-medication will not be accounted for. According to other research in the Colombian context, this would be the case for approximately 30% of the population (Camacho & Meija, 2017).

A few existing studies confirm the relationship between pesticide use in agriculture and adverse health outcomes. Amoatey et al. (2020) present a review of epidemiological and clinical studies, finding that greenhouse farm workers globally report respiratory problems, neurological symptoms, and skin irritations. For female health outcomes specifically, Dias et al. (2019) find a relationship between pesticide use in Brazil's soybean production, and fertility issues and miscarriages. They find differences in impact between upstream and downstream communities due to water pollution, highlighting the connection between environmental and human health. In Colombia, Camacho & Meija (2012) use a quasi-natural experiment and finds that the aerial spraying of pesticides to combat the growing of illicit crops increases the number of medical visits related to miscarriages. The latter study has been influential example for the model adopted in this study, including the use of RIPS data for the dependent variable, and control variables on land size, population, socioeconomic background, and healthcare.

Methodology

The chosen empirical approach for the analysis is an Ordinary Least Squares (OLS) regression. According to Gauss-Markov theorem, OLS is the best linear unbiased estimator when five assumptions are met. OLS is unbiased if the independent variables are exogenous to the model and if there is no perfect multicollinearity. Furthermore, the method is the best linear model if the errors are normally distributed, serially uncorrelated, and homoskedastic.

Descriptive Statistics

Dependent variable

Condition O (ConditionO) - To isolate the health impact of pesticide use on women specifically, the main dependent variable is medical visits classified under diagnosis type O, related to pregnancy, childbirth, and the puerperium. Following findings from Asmare et al. (2022) and London et al. (2013), the expectation is to find a positive relationship between pesticide use and Condition O type visits. As was expected, the distribution of the variable is right-skewed, whereby the mean is greater than the median, because many municipalities have relatively few inhabitants, and thus a low number of absolute doctors' visits. *Figure 3* shows that after log-transforming the variable, the dependent variable approaches a more normal distribution.

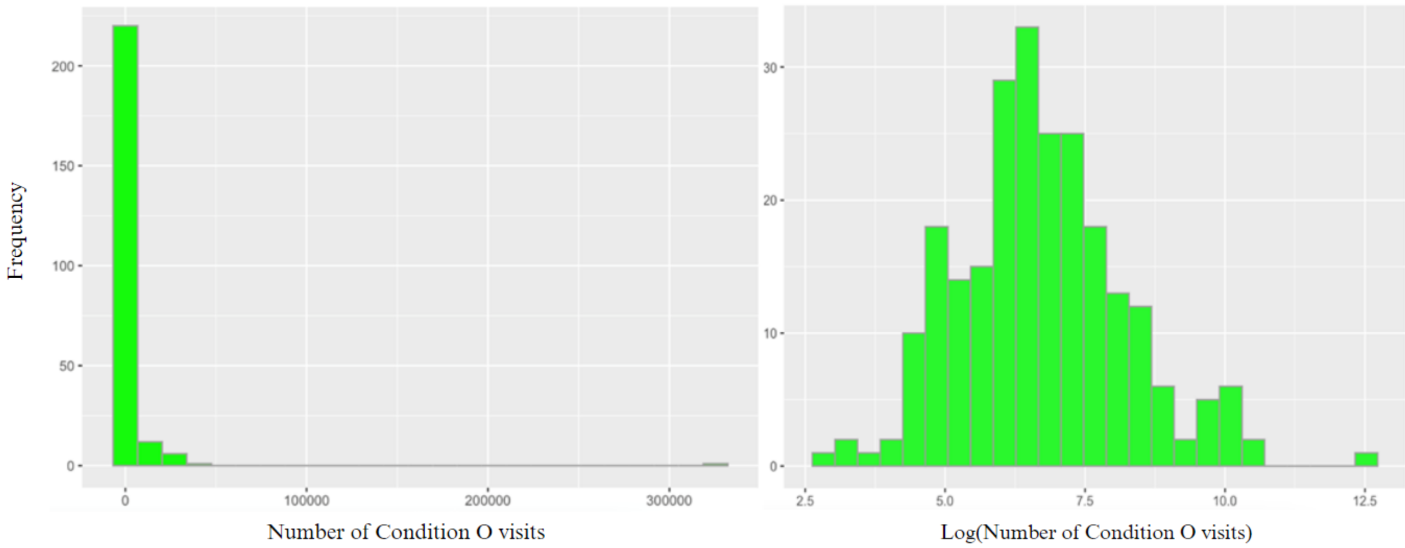

Figure 3 - Frequency distribution of the dependent variable before (left) and after (right) the log-transformation

Independent Variables

The independent variables are similar to those used by Camacho & Meija (2012), who based their control variables on a municipal panel constructed by CEDE (Research Center for Economics and Development at Universidad de los Andes), using data on economic, geographical and social characteristics at the municipal level in Colombia.

Square kilometers of flower farms (KmFarms) - As there is no publicly available data on the exact types and amounts of pesticides used in Colombia's cut-flower business, pesticide use is proxied by square kilometers of flower farms. This variable is based on data on hectares of flower farmland per municipality, and is provided through the IcA, the dataset contains individual flower farms, their location, and their size in 2010. From this data, the growth rate of the land is extrapolated based on the growth rate land use (in ha) of flower production and is taken to be 33,23% from 2010 to 2019. The variable is then transformed from hectares to square kilometers. Out of 240 municipalities, only 65 have some level of cut-flower farm activity.

Female population (FemPop) - An important control variable in the model is female population. Female population is expected to significantly relate to the number of medical visits for type O (or any other type) of visits, simply due to the assumption that a higher number of female inhabitants will lead to a higher number of medical visits, *ceteris paribus*. As the outcome variable is specific to female medical visits, the population to control for is the female population. We assumed that the female population is proportionately equivalent to the national sex ratio, which is 50.9% female out of the total population, as reported by the World Bank (2019).

Multidimensional Poverty Index (MPI) - A second control variable is the Multidimensional Poverty Index, developed by the UN Development Program, UNDP. This index looks at several different dimensions of poverty, or deprivation, taking into account more than just monetary poverty. There are thirteen categories and these include among others, lack of sanitation, child services, education, and healthcare. The MPI is expected to relate to women's health outcomes, as poverty is linked to low quality health provision, lack of knowledge, lack of proper sanitation, and thus to increased vulnerability to adverse health effects (WHO, 2002). By adding the MPI as an independent variable to the model, the number of medical visits that may stem from poverty can be controlled for. The MPI is obtained in the 2018 Census and is reported by DANE, and is expressed as a percentage of the population.

Lack of access to healthcare (HealthAccess and TotalProviders) - For similar reasons to including the MPI, lack of access to healthcare is another important variable potentially impacting the number of medical visits. There are two data sources on this, each with its benefits and limitations. Data on healthcare deprivation, variable *HealthAccess*, is collected in the 2018 census and is part of the MPI. Municipalities differ strongly in their share of the MPI that can be attributed to deprivation of healthcare, and therefore there is no expected high multicollinearity between the MPI and healthcare deprivation. The given percentage is the sum of the lack of access due to healthcare deprivation and lack of health insurance. The second healthcare variable is the number of total healthcare providers registered in each municipality as recorded by the IPS. This list includes all registered healthcare professionals such as GP's, nurses, specialists and assisting personnel. As rural areas generally have less access to healthcare and fewer healthcare providers, it there is an expected negative relationship between *HealthAccess* and the number of Condition O visits, and an expected positive relationship between the number of healthcare providers and the number of Condition O visits (Peters et al., 2008).

Table 1- Summary Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Municipalities	240	-	-	-	-
Condition O	240	3861		19	325 494
Hectares of farms	240	52.57		0	2253
Female population	240	18466		866	1 200 399
MPI	240	32.77		4.5	81.50
Health access	240	4.29		0.2	40.2
Total providers	240	244		0	37201

Regression Model

Based on the related empirical work of Dias et al. (2019) and Camacho & Meija (2012), we expect to find a positive relationship between pesticide use in the cut-flower business, proxied by square kilometers of flower farms, and medical visits for diagnosis type O, related to pregnancy, childbirth, and the puerperium. The bivariate model is therefore specified as follows:

$$ConditionO_i = \beta_0 + \beta_1 KmFarms_i + \epsilon_i$$

Where $ConditionO_i$ is the total number of medical visits and $KmFarms_i$ is the number of square kilometers of flower farms, for i^{th} municipality. The error term in this model, ε_i, captures the variation in the dependent variable that is not explained by the model.

Due to the strong right skewness of the dependent variable and the independent variable of interest, a log transformation is applied to both variables. The model with this transformation is a better fit for the data, suggested by a simple Pearson correlation test, where without the log transformation of the variables the correlation is very weak and insignificant, and after the log transformation the correlation is 0.381 (p < 0.000). With the log transformation, the coefficient for kilometers of farms can be interpreted as an elasticity, e.g. the percentage change in the dependent variable for every one percent change in the independent variable. After transforming the variables, the model becomes as follows:

$$lnConditionO_i = \beta_0 + \beta_1 lnKmFarms_i + \epsilon_i$$

A simple bivariate regression of this model finds the estimate of the coefficient to be 1.13, statistically significant at the 1% level ($p < 0.000$). This means that a one percent increase in hectares of flower farms increases medical visits for condition O type diagnoses with 1.13 percent, *ceteris paribus*. However, this model is not controlled for any other variables, and their effects will be absorbed into the error term which could lead to omitted variable bias. The idea that this model is not the best fit for the data at hand is also implied by the relatively low R-square of 0.142. Based on research of Camacho & Meija (2012) and the control variables supplied by the Research Center for Economics and Development at Universidad de los Andes, the model is expanded by adding the control variables for female population, MPI and healthcare access. The variable for female population, *FemPop*, is added because it is assumed that a higher number of female inhabitants will lead to a higher number of medical visits, *ceteris paribus*. The variables *MPI* and *HealthAccess* are added because of the assumed positive relationship between poverty and adverse health outcomes, and the negative relationship between access to healthcare and adverse health outcomes. Estimating this model finds that a 1 percent increase in hectares of farms leads to a 0.943 percent increase in the number of condition O type medical visits, *ceteris paribus*. This finding is significant at the 1 percent level. Results from the multivariate models are presented in Table 2.

Although a positive relationship was expected between population and Condition O visits, which is confirmed by the high positive correlation between the two, the results from the regression imply that population does not have a large impact on the number of medical visits. The coefficient suggests that an increase of 1000 inhabitants is associated with a 0.007% increase in condition O type visits. This is not a surprising result, as population size is not a determinant of health outcomes in and of itself, but a larger population can be linked to other factors such as reduced poverty and increased healthcare access. Yet these variables are controlled for, and both coefficients for the MPI and healthcare access are insignificant at the 5 percent level.

Table 2 – Results of the regression models

Model	(1)	(2)	(3)	(4)	(5)	(6)
KmFarms	0.943***	0.962***	0.982***	0.901***	0.607*	0.671**
FemPop[2]	(0.000***	-	-	-	-	-
MPI	-0.005***	-0.012’	-0.008	-0.000	-0.043*	-0.029
HealthAccess	0.002	-0.003	-	-	-	-
TotalProviders	-	-	0.175***	4.128***	0.147***	0.719*
R-square	0.2959	0.146	0.225	0.242	0.3824	0.302
BP-test	0.01933	0.93427	0.9427	0.000	0.9266	0.302

Standard errors in parenthesis.
p < 0.05, ** *p* < 0.01, *** *p* < 0.001

To test the OLS assumptions, a Breusch-Pagan test is applied to identify potential heteroskedasticity for Model 1. The presence of heteroskedasticity would violate the Gauss-Markov assumption of a constant variance of the residuals, which would lead to a biased t-statistic and thus an unreliable p-value. The studentized Breusch-Pagan test for Model 1 returns a p-value of 0.01933, meaning we can reject the null hypothesis that the model is homoskedastic. The standard errors used to determine significance may not be reliable. For this reason, several additional model specifications are tested.

In the second model, population is excluded from the specification. This is because population is not expected to be a causal determinant of condition O type visits and its estimated coefficient was found to be insignificant. The R-square of Model 2 without population is lower than the Model 1 specification where population is included, but it is no longer found to be heteroskedastic, meaning the p-values are reliable. In the third model, the variable healthcare access is replaced by total providers.

Healthcare access is replaced by total providers for two reasons. First, a simple correlation test finds that Healthcare Access, measured as a percentage of the population that *lacks* access to healthcare, is positively correlated with Condition O type visits. This is unexpected, as it implies that a lack of access to healthcare actually increases healthcare visits. Second, its

[2] The coefficients presented in the table for the variables FemPop and TotalProviders have been multiplied by 100 for ease of interpretation. See original output in Appendix B.

estimated coefficient is found to be insignificant in different model specifications. As healthcare access is measured as part of the MPI, it is possible that the effect of healthcare access is strongly related to poverty and thus it may be difficult to separate their effects. Therefore, it is chosen to include Total Providers into the model.

Comparing the three models shows that with or without including population, the estimated coefficient for kilometers of farms only marginally changes and remains to be significant at the 1% level for all three models ($p < 0.000$). Furthermore, the coefficient for total providers is statistically significant at the 1 percent level, implying that an increase of 100 healthcare providers leads to a 0.175 percent increase in medical visits. Lastly, the R-square increases from 0.146 for Model 3 to 0.225 for Model 4. Therefore Model 4 is our preferred specification. Testing Model 3 and 4 for heteroskedasticity does not return a statistically significant result ($p = 0.9427$) and thus we fail to reject the null hypothesis that there is heteroskedasticity. However, upon examining the model visually, there seem to be some outliers that may be problematic.

Robustness Checks

The first outlier is the municipality of Medellin. This is visible in *Figure 3*, where the number of Condition O type medical visits in Medellin are far higher than in any other municipality. Medellin is likely an outlier in part due to its sheer population size, with over 2.5 million inhabitants. The size of the city likely also impacts its healthcare facilities, as there are often more and better healthcare services in urban areas, which could lead to people coming to Medellin specifically for healthcare treatments. In that case, the number of Condition O type medical visits in Medellin could be overestimated. Therefore, as a robustness check, the outlier municipality of Medellin is manually removed from the model.

Testing the Model 4 specification without including Medellin does not change the sign or significance of the estimated coefficients. However, the data now seems to be heteroskedastic, and thus a robust regression is applied. This results in the identification of three further outliers, these are the municipalities that are all adjacent to Medellin: Bello, Envigado, and Sabaneta - all of which are large municipalities with populations exceeding 200 000. For the same concerns about overestimating the true number of Condition O type visits as Medellin, the outliers are manually removed from the data. Doing so does not change the size or significance of the variable of interest, neither does running Model 1 with a robust regression to combat heteroskedasticity.

As a final robustness check, the model excluding *Female Population* and including *Total Providers* is tested for those municipalities that have some level of cut-flower farm activity. This is done because only 65 out of 240 municipalities grow flowers. *Figure 2* showed that these municipalities seem relatively clustered around the cities of Medellin and Bogota. Again, the results from Model 5 show that the sign or significance of the estimated coefficients do not change. It shows that among farm-producing municipalities, a 1 percent increase in the square kilometers of farms is associated with an 0.6 percent increase in condition O type medical visits. Removing Medellin as an outlier for the same reason mentioned above does again not change the significance of this result, as shown by Model 6. Thus, the results can now be interpreted.

Results

All models tested find a significant positive relationship between pesticide use in the cut-flower industry and medical visits for women with issues related to pregnancy, childbirth, and the puerperium. This is in line with what the theory predicted, as well as with evidence from previous case studies suggesting a causal link between pesticide use and adverse health outcomes. Holding all else constant, the preferred specification of Model 4 estimates that a 1 percent increase in square kilometer area of flower farms increases the number of medical visits for O type diagnoses by 0.98 percent ($p < 0.000$). Although the size of the coefficient marginally changes with different model specifications, the sign and significance of the coefficient remain the same, even against several robustness checks.

The MPI is the only variable that is negatively correlated with all other variables in the model, and its estimated coefficient is negative as well. Yet the estimation is not significant so the result cannot be interpreted. This means that there is no significant difference in medical visits between municipalities with a high MPI versus those with a low MPI. That result is not in line with the one from findings of the WHO (2002) which predicted a positive relationship between poverty and adverse health outcomes. One reason why the MPI would not significantly impact Condition O visits, is that despite poverty increasing the risk of adverse health outcomes, it is possible that pregnant women in regions with high poverty resort more to informal healthcare, potentially leading to an underreported number of medical visits. This would be in line with

Sudhinaraset et al. (2013) who find that globally, low-income regions rely more on informal healthcare, which will not be reported in the RIPS dataset.

A second reason why poverty is not significant could be related to access to healthcare. It is possible that people living in municipalities with a low number of healthcare providers choose to visit larger nearby municipalities for healthcare, especially for specialized treatment. This mobility could inflate the number of visits in urban areas, and again underestimate the true number of type O diagnoses in municipalities with a high MPI. By adding a variable related to access to healthcare, *HealthAccess or Total Providers*, the effect of the MPI will be further mediated because part of the impact of poverty on health outcomes can be ascribed to the relationship between poverty and a lack of access to healthcare. It is therefore surprising that the estimated coefficients for healthcare access are very small, and that *HealthAccess* is insignificant. However, a similar argument to that of the insignificance of the MPI could apply in this case as well. Taking into account cross-municipal mobility could therefore be a good avenue for future research.

While proven robust across different model specifications, three main limitations arise mainly due to the availability and nature of the data used. First, the RIPS data on medical visits is not specified for gender, age, or occupation. To circumvent the lack of data on gender, the type of medical visits used was chosen to be specific for women, although it only concerns a small segment of the female population who got pregnant. Using gender, age, or occupation specific data provide further insight on whether women are also at an increased risk of respiratory, dermatological, neurological, or other issues associated with pesticides. Second, the data on flower farms is relatively dated and lacks an exact farm location. Data for 2019 is therefore extrapolated, and assuming that the growth in hectares of land has followed a linear trend. This mean we assume no significant efficiency gains were achieved. This is not an ideal assumption to make, and further inquiries could aim at retrieving accurate data for the year 2019. Furthermore, including more geo-spatial variables to understand the dispersion of the farms throughout the country, including whether a farm is located in an upstream or downstream area, could provide further insight into how the impact of pesticides changes according to environmental conditions.

All in all, the results of the regression analysis confirm that within Colombia, women living in municipalities with cut-flower farm activity face more reproductive health concerns that increase with the number of hectares used to grow flowers. As findings from the literature review suggest, this is likely not only due to direct contact with pesticides, but also through indirect contact as these pesticides leak into the soil and the environment (London et al., 2013; Asmare et al., 2022). Furthermore, many cases of type O conditions may be underreported due to the nature of their concern, and because a large share of people in poverty may resort to informal healthcare, potentially underestimating the true impact of pesticides on female health outcomes (Sudhinaraset et al., 2013).

4. Analysis

To understand the impact of pesticide use in the cut-flower business on women's health in Colombia, it is necessary to put the case of Colombia in broader perspective. As trade is a key factor in the export-led growth strategies of many Global South nations including Colombia, pesticide use in the cut-flower business provides an illustration of how practices within Colombia are incentivized by national government policies which are again influenced by international trade relationships. To understand these relationships and incentives, the economic discipline provides key insights. Within the discipline itself, various subdisciplines have different perspectives on the costs and benefits of trade. The following analysis will therefore first contrast neoclassical and ecological economic theories on international trade, and then apply insights from these theories to the case of the cut-flower business.

Economic perspectives on trade and agribusiness

In the dominant neoclassical paradigm, one of the central principles of economics is that resources must be allocated efficiently (Brand-Correa et al., 2022). The aim of economic activity is to achieve Pareto efficiency; a situation where not one party can be better off without making the other party worse off. Liberalizing trade is a key factor in increasing this efficiency in the global allocation of resources. According to the Hecksher-Ohlin model of comparative advantage, trade allows countries to specialize according to what they relatively have in abundance, which will over time increase their efficiency and lower production costs. As each country produces and trades according to their relative advantage, the total gains from trade are maximized (Giljum & Eisenmenger, 2004). These ideas of efficiency and trade are in turn closely linked to the concept of GDP growth. Under optimal resource allocation, facilitated by international trade, the surplus accrued to each country is maximized, increasing the size of the pie. Growth is again associated with overall benefits to society including reduced poverty and increased life expectancy, although it is recognized that the gains from trade are not always evenly distributed (ibid). Thus, from the neoclassical perspective trade liberalization is seen as a win-win as it contributes to the increase in the GDP of participating countries, which is generally associated with development, or progress.

In relation to agribusiness, the creation of new technologies such as GMOs and agrochemicals during the Green Revolution presented a great increase to efficiency. Together with technological innovations and reduced trade barriers, this neoclassical focus on efficiency contributed to the emergence of industrial agriculture as we know today (Krausman & Langthaler, 2019). Yet at the same time, the industrialization of the agri-food system is linked to numerous environmental problems such as soil degradation, water pollution, and greenhouse gas emissions (Gomiero et al., 2018). From the neoclassical economic perspective, environmental and social problems are seen as externalities, and the solution to them is believed to stem from the market. Through taxation, assigning property rights, and government regulation, “external” issues are internalized, which should result in more efficient outcomes (Brand-Correa et al., 2022). Yet these neoclassical assumptions are increasingly challenged by ecological economists.

The central difference between ecological and neoclassical economics is that ecological economists see the economy as a subsystem of society, and society as a subsystem of the biosphere. This means that economic processes are constrained by the earth's biophysical limits. EE scholars emphasize that many environmental problems are caused by economic activity continuously exceeding planetary boundaries, and that this overexploitation of the earth’s resources is inherent to the current economic system where growth and efficiency are the main indicators of progress. For this reason, ecological economists analyse economic processes beyond monetary indicators by looking at resource use and social outcomes through integrating natural science methodology (Brand-Correa et al., 2022). Furthermore, ecological economists increasingly criticize the so-called ‘growth-paradigm’, whereby GDP growth seems to have become an end-in-itself in neoclassical economic thinking. Notably absent from GDP are metrics for care work and wellbeing, whereas economic activity of socially less-desirable industries are included, such as trade in weaponry (Hickel et al., 2021). It was Simon Kuznets, the economist who developed the concept of GDP, who warned against this in 1962 stating that "Distinctions must be kept in mind between quantity and quality of growth, between its costs and return, and between the short and the long term. Goals for more growth should specify more growth of what and for what" (Kuznets, 1962, as cited in European Commission, 2012). With that statement in mind, one EE theory suited to analyzing the global cost and benefits associated with our economic activity, including activity of the cut-flower business, is the theory of Ecologically Unequal Exchange.

Originating from a combination of ecological-economic and political-economic thought, the theory of Ecologically Unequal Exchange (EUE) is a newly emerging theory that aims to quantify the asymmetric flows of biophysical resources from the Global South to the Global North, and it links this process to the neoclassical underpinnings of international trade (Givens et al., 2019). The theory starts from the idea that rich countries through their economic, technological, or military power disproportionately have access to global resources (Giljum & Eisenmenger, 2004; Dorninger et al., 2021; Givens et al., 2019). EUE research focused on quantifying these flows looks looking at both monetary and nonmonetary exchanges.

Looking at monetary value, EUE research finds an unequal exchange due to price disparities between the North and the South (Giljum & Eisenmenger, 2004; Hickel et al., 2022; Hickel et al., 2021; Hornborg, 2014). Prices for comparable goods are much lower when produced in the South. This is in part attributable to low wages paid to workers, as Global South wages are on average one-fifth of the level of wages in the North (Hickel et al., 2021). These wages tend to stay low compared to the North, partly because productivity gains in the North are more likely to be distributed to the workers, due to the relatively strong bargaining position of labourers and unionization (Giljum & Eisenmenger, 2004). More importantly, EUE highlights that historical and contemporary power relationships keep the cost of labour and resources in the South low, for instance through immigration policy restricting migration from South to North, preventing international wage convergence (Hickel, 2021). Therefore, given a good that requires the same amount of labour and resources in both parts of the world, for every unit that Global South countries import from the North, they have to export five times as much to reach the same level of absolute income. Through this geopolitical power imbalance between the North and South, rich countries disproportionately have access to cheap material resources.

The global trade system is then key in understanding the unequal distribution of material resources. Through low prices, Global North countries can appropriate a large amount of biophysical resources used to sustain its high level of consumption. These resources are mainly extracted in the Global South, where they produce large amounts of waste and environmental damage (Dorninger et al., 2021). By increasingly relying on resource extraction in the South, to fuel consumption in the North, wealthier nations are effectively outsourcing the environmental burden associated with their economic development, because high-income countries depend on resource-intensive technologies and infrastructures for their own economic growth. To date, although there are some trends showing the decoupling of economic growth and emissions, there is no evidence that GDP growth can be decoupled from material use (Kraussman et al., 2017; Wiedmann et al., 2015). EUE theorists therefore argue that other metrics need to be considered in the economy beyond the monetary value, such as tons of materials, hectares of land, or person-year equivalents of labour. Empirical research looking into this relationship finds that in 2015 alone, the Global North's net appropriation of labour and resources amounts to as much as 10.1 billion tons of raw material equivalents and 182 million person-years of embodied labour (Dorninger et al., 2021; Hickel, 2021).

In mainstream economic theory, asymmetric trade flows of monetary or nonmonetary resources are considered to increase market efficiency. As previously described, the assumption is that under liberalized trade, each country can specialize in what they produce cheapest relative to other countries, and this over time leads to increased GDP for all participating countries. From the neoclassical standpoint, differences in environmental standards are seen as reflecting different preferences between environmental quality and income, resulting in different trade-offs that countries choose to make. In relation to environmental problems, proponents of free trade argue that economic growth would increase tax revenues which could be invested in better environmental protection. Opposing this position, EUE theorists argue that free trade leads to a polarization of environmental standards between the Global North and the Global South, because rich countries are shifting their production chains to the South (Giljum & Eisenmenger, 2004; Kraussman et al., 2017). Furthermore, they criticize the assumption that the gains from trade could pay for all the necessary mitigation costs, arguing that these gains are often not distributed fairly. Therefore, EUE theory posits that which goods are traded and at what cost, matters for the growth potential of individual countries. Quantifying the flows of these resources shows that unequal trade relationships arise from and reproduce socio-economic inequalities on a global scale (Dorninger et al., 2021). Previous studies examining the link between EUE relationships and health outcomes, have found a relationship between EUE and maternal mortality (Rice, 2008), infant mortality (Jorgenson, 2009), and deaths from air pollution (Hekmatpour & Leslie, 2022).

To summarize EUE theory, the geopolitical power of Global North nations limits wage and price convergence between the North and South. Through this, Northern countries appropriate labour, land, and resources from the South which in turn leads to an unequal distribution of the environmental and health burden associated with this. Trade is an instrumental factor in this process because the unequal exchange of monetary resources on the world market depresses the potential revenues necessary for sustainable progress in the South. At the same time, this maintains high levels of income in the Global North, allowing them to maintain high levels of material consumption that are neither equitable nor sustainable (Hickel et al., 2022). In essence, the Global South is both “a tap for resources and a sink for waste” within the global economic system (Givens et al., 2019).

Despite their differences, neoclassical and ecological economic theories do not necessarily contradict each other. They share an understanding of the issues associated with certain economic activities, but they emphasize different causal mechanisms, and therefore propose different solutions. In the case of environmental problems, neoclassical economists see the issues as market inefficiencies, which can be solved by getting the price right. EUE scholars, on the other hand, see environmental problems as inherent to the current economic system, where trade is based on unequal power relationships, leading to disproportionate impacts in the Global South.

To apply these ideas, this paper will take an ecological economic standpoint, meaning that the cut-flower business in Colombia can be understood as a sub-element of the international market which is again embedded in our economic and ecological system. What follows from this is that outcomes within the business, such as adverse reproductive outcomes for women, should be seen in a broader perspective. The regression analysis quantified the causal relationship between pesticide use and Condition O type visits, but this approach fails to explain why pesticides are used in the first place. To understand agricultural practices in the cut-flower business and their impacts more broadly, the following section of the analysis consists of two elements. First, it will argue how neoclassical principles were key in informing government policy related to agriculture and trade, incentivizing practices within the cut-flower industry that impact women’s health to date. Second, it will use EUE theory as a framework to understand how international power dynamics shape unequal distributions of monetary and nonmonetary resources, linking this unequal exchange to disparate health outcomes between and within countries.

Neoclassical principles and agricultural practices

Historical developments in the agricultural system illustrate the impact that neoclassical thought had in shaping agricultural practices. From the 1960's onwards, many governments in the Global South aimed to achieve an export-led growth trajectory by exploiting their comparative advantage (Giraldo, 2019). As countries will export those goods that use a country's most abundant input factor, many Global South countries specialized in the production of agricultural products due to the abundance of cheap labour and land. Paired with new technologies developed during the Green Revolution, such as genetically modified organisms and agrochemicals, crop yields dramatically increased and agricultural output more than doubled over the last 50 years. This increase in output and exports is seen as a key driver of economic development, which is in turn linked to increased labour force participation of women and reduced gender inequality (Duflo, 2012). But through trade liberalization, pressures to compete internationally resulted in unsustainable practices. Rather than expanding the production of traditional and local agricultural commodities, many countries in the Global South shifted towards high-value non-traditional agricultural exports (NTAEs) destined for Global North markets. This increased the share of NTAEs from developing countries, but also decreased food production for domestic consumption and decreased food insecurity (Ferm, 2008; Patel-Campillo, 2010). Additionally, the export-led growth strategy incentivized the use of pesticides, specialization in monocrops, and the expansion of land use – practices that are all associated with environmental and social problems (Patel-Campillo, 2010; Hickel et al., 2021).

As to not fall to the risk of inverting cause and effect, human beings have always tried to maximize their own gains, which could with today's knowledge be interpreted as a sort of 'growth mindset'. Nevertheless, when growth became a national concern from the 1960's onward, the policy recommendations to achieve growth were based on neoclassical economic theories, and among this trade liberalization was a relatively uncontroversial policy (Rodrik, 2003; Wijnands et al., 2007). By the 1980's, neoclassical economists converged on a set of policies later dubbed as the "Washington Consensus", where trade liberalization was again a key point (ibid). This one-size-fits-all approach, widely promoted by international organizations such as IMF and the World Bank, has since been broadly contested by economists throughout the discipline, but the ideas nevertheless had an impact on contemporary development policy in the Global South.

This impact is also evident in the cut-flower industry of Colombia. From the 1960s onwards, guided by the same neoclassical principles, the World Bank recommendations were widely implemented in Colombian economic policy (Richani, 2012). Export-led economic growth through agricultural modernization became the primary aim of government policy in Colombia. with the cut-flower sector as one of the key industries – with success (Patel-Campillo, 2010 p. 2524; Patel-Campillo & Del Rosario Castro Bernardini, 2015, p. 104). *Figure 4* shows the development of exports in the sector for the period 1970-2018, showing that the Colombian cut-flower business experienced relatively steady growth over the last 50 years.

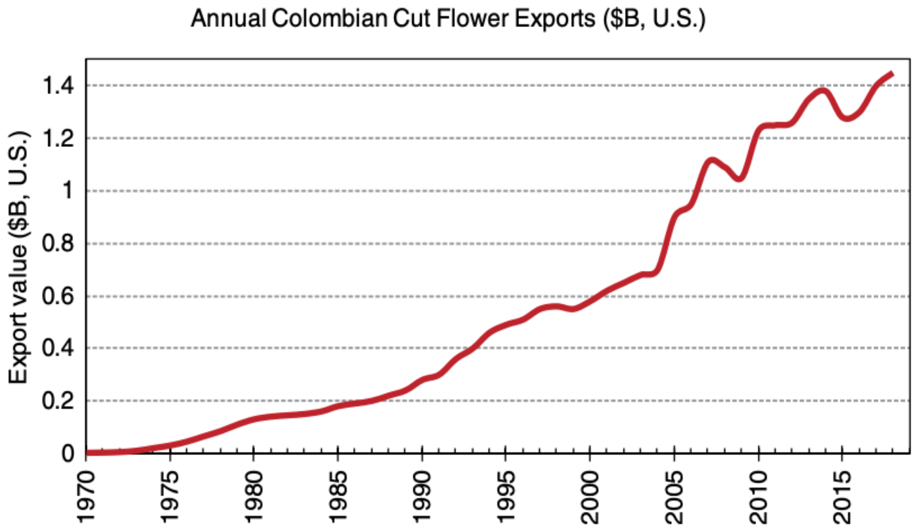

Figure 4 - Exports of Colombian cut-flowers from 1970 to 2015, source: Faust & Dole, 2021.

For the cut-flower industry, the government aimed at attracting foreign investment, and expanding production. Paired with cheap labour costs and lax environmental regulation, these policies helped Colombia gain comparative advantage in the global flower market (Patel-Campillo, 2012). From a mainstream economic perspective focusing on monetary value, exploiting this advantage improved market efficiency and maximized the gains from trade. Through this, the cut-flower industry in Colombia became a significant contributor to the country's economy and created labour market opportunities for women. The question this begs is if these benefits outweigh the costs.

Within the cut-flower industry, there are signs that women are disproportionately impacted by cost-cutting measures. To maintain comparative advantage, it is key for flower farmers to keep costs of production as low as possible. Considering wages are the single largest expense for flower growers, common ways to achieve this are offering flexible employment contracts and low wages. As the majority of the low-level workers in the sector are women, the impact of these policies will happen along gender lines. Without the protection of a formal employment contract, women are more vulnerable to exploitation by their employer and could be denied rights such as sick leave or maternity leave (Ferm, 2008; Sanmiguel-Valderrama, 2007). Additionally, insecure employment contracts may make it difficult for workers to organize themselves, for instance to hold employers accountable for safety standards when handling toxic pesticides. Reports and interviews with women working on flower farms highlight their precarious working conditions and denial of workers' rights. Earlier attempts at unionization resulted in discrimination against union members. One female flower farm worker describes her experience of being unable to leave the farm she is at because companies perceive her as a '*guerillera*' due to her association with a trade union (Wright & Madrid, 2008). Paired with job instability in quieter periods and potential workplace violations, the impact of the cut-flower business on the health of women working in the industry may stretch far beyond the physical implications. This also holds true for the impact of pesticide use.

Using pesticides is another common strategy to reduce costs (Pereira et al., 2021). As has been explained before, these chemicals present a risk to human and environmental health through multiple pathways and are linked to a range of health issues including respiratory, dermatological, and neurological issues for both men and women. Women in particular face heightened and gender-specific risk due to biological factors increasing their chances of pesticide related illness, such as reproductive issues (London et al., 2013). The regression analysis confirms this by the positive relationship found between cut-flower farm activity and medical visits related to pregnancy, childbirth, and the puerperium, suggesting that pesticides do not only affect women working directly in the industry but potentially also women living in areas surrounding the farms. Furthermore, reproductive health issues are not merely a physical concern. The psychological impact of reproductive issues cannot be underestimated. Miscarriages are for instance strongly associated with anxiety, depression, and suicide (Quenby et al., 2021). It is therefore concerning that women in the cut-flower industry of Colombia report a lack of appropriate accommodation from their employer when encountering health concerns (Ferm, 2008). All in all, pesticide use and its associated impacts should not only be seen as a cause, but also as a symptom of an agricultural system governed by the continuous quest for efficiency and growth. In turn, agricultural practices are incentivized by structural dynamics underlying international trade.

Cut-flower trade and Ecologically Unequal Exchange

Adopting an EUE lens, it is necessary to understand how power relationships shape outcomes of unequal exchange that impact the health of women in Colombia. Without quantifying these flows specifically, there seems to be evidence of an unequal exchange of both monetary and material resources between Colombia and the Global North. This starts with price differences between the North and the South, which are also evident in the case of the cut-flower business. For comparable goods, workers in the cut-flower industry of Colombia receive a much lower share of the value of their products than producers in richer countries. A worker in Colombia caring for the flowers, risking exposure to pesticides that are illegal elsewhere, would get paid less than US $1.85 per hour, but as soon as the plane lands in the US, the person unloading the box would receive at minimum US$7.25 - that is if minimum wage laws are adhered to.

These price differences are perpetuated by power imbalances within and between countries. Within Colombia, the low-level workers in the industry are mainly women from marginalized backgrounds, such as indigenous or African descent. The farms, on the other hand, have historically been controlled by a small group or larger exporting firms, owned by the nation’s elite, mainly of European descent. Lobbying power of these farm owners through institutions such as Ascolflores has resulted in national legislation keeping minimum wage low, and reducing job security (Patel-Campillo, 2011; Sanmiguel-Valderrama, 2007). This could contribute to a lack of respect and recognition for the workers at a micro level, being denied overtime payment, maternity leave, the right to unionize, and other key tools to achieve better working conditions. Through this, women in the cut-flower business lack protection through government legislation, which is both keeping their wages low and exposing them to harmful pesticides.

Between countries, pesticides and cheap female labour are thus used to keep prices low, and these low prices fuel Global North demand for Colombian flowers. Especially around peak demand times during holidays such as Valentine’s Day and Mother’s day, pressure on the workers increases dramatically, with some women reporting to work up to 80 hours per week (Ferm, 2008). Flower production being associated with pesticide use, this hints at the potential for unequal exchange, whereby the goods are exported to the Global North and the environmental and health burden stays in Colombia. Although no specific research has been done to quantify potential unequal exchange relationships in the cut-flower business of Colombia specifically, there are studies examining the global flows of pesticides. Tang et al. (2022) find that consumption in the Global North has a substantial contribution to pesticide use in the Global South, with wealthier nations generally having larger pesticide footprints.[3] As over 95% of all flowers produced in Colombia are exported to Global North markets, and the industry uses a high amount of sometimes illegal pesticides, there is an indication of unequal flows of pesticides within the cut-flower industry as well.

Thus, according to the theory of Ecologically Unequal Exchange, the cut-flower business in Colombia should be understood in terms of unequal trade relationships. Through wealth, political power, and preferential trade agreements among other things, the Global North effectively outsources the environmental burden associated with its consumption pattern. These trade relationships are shaped by the international division of labour and could be seen as a historical remnant of Colonization in the 16th century (Giljum & Eisenmenger, 2004). More recently, programs from international organisations such as the IMF and the World Bank have incentivized governments to pursue export-led growth strategies. In Colombia, this has led to agricultural intensification focused on non-traditional agricultural exports destined for Global North markets, where cut-flowers became a key industry. Through this, the use of pesticides and other cost-cutting measures are incentivized by these international institutions, which is exemplified by the case of the cut-flower business. Government policy related to the cut-flower sector has been successful at achieving impressive growth of the sector, yet as the regression model in this thesis has shown, this may come at the cost of women's health.

[3] Some Global North countries that are large exporters of agricultural goods, such as the Netherlands, are at the same time large importers. The products imported are often produced under fewer environmental regulations, meaning an equal amount of exports and imports of a certain good does not necessarily equate to an equal exchange of pesticides. In case of the Netherlands, despite being a large exporter, the country is still a net-importer when taking into account pesticides embedded in traded goods, contributing to their large 'pesticide footprint'.

5. Discussion

Having established the causal relationship between pesticide use and health outcomes for women in the regression model, linking this outcome to incentives underlying international trade in the analysis, the findings of this thesis have thus far been explanatory rather than normative. Two main concerns arise from taking a purely economic perspective. First, despite their differences, both ecological and neoclassical economics mainly focus on the distribution of costs and benefits related to the distribution of resources, neglecting cultural and political aspects.[4] Second, although critical EUE scholars argue that the unequal exchange of resources leads to unjust outcomes, they fail to explain how this would lead to obligations for the Global North. To fill this gap in EUE theory, and to come to an interdisciplinary understanding of the problem, a more normative evaluation is necessary. Therefore, this discussion zooms into the plight of women from a social justice perspective, with the aim of opening up the debate on who has what responsibilities to combat unjust practices within this system.

Who has the responsibility to fight oppression is often not straightforward in cases of structural injustice, which can be understood as oppression that is not the result of an intentional act by any clearly identifiable agent, but rather as the outcome of institutionalized social, economic, and political forces that put people under the 'systematic threat of domination or deprivation of the means to develop and exercise their capacities' (Young, 2011). As structural injustice cannot be attributed to a clear individual, group, or state, the lines of responsibility blur. The case of the cut-flower business provides an illustration of this.

As has been argued in the analysis, women in the cut-flower business face hardship through different pathways. Most workers in the industry are women, many of marginalized backgrounds, who work long hours, often underpaid, and under insecure employment contracts. They are often denied worker's rights such as overtime payment or maternity leave, and attempts to unionize are followed by intimidation or discrimination. Women report to not have adequate protection gear against pesticides, leaving them disproportionately exposed to harmful chemicals which are linked to a range of health concerns, yet they are not taken seriously when bringing this up to employers.

[4] Resources in this case refers broadly to socio-economic resources necessary to achieve an adequate standard of living such as labour, land, money, and health.

When speaking of who is responsible for this, it is easy to point at the managers and owners of the farm. They are the ones in direct contact with the workers, intimidating and underpaying them, and so they are the ones who have the moral responsibility not to cause another harm. But imagine an instance where the managers and owners all fulfill their moral responsibilities: Minimum wages are paid in accordance with the law, unionization allows women to get better personal protective equipment and to reduce their working hours, and they are respected and taken seriously when bringing up concerns. Could we now say that justice has been achieved?

Looking merely at moral responsibility, the answer could be yes, but there is a difference between moral responsibility for one's own actions, and political responsibility for one's position of power (Gädeke, 2021). Even if moral duties are fulfilled, the women would likely still make minimum wage, barely equal to subsistence, they would work manual labour jobs with few opportunities to get promoted, and they would still be trapped in a position where they lack a real voice or alternative, leaving them vulnerable to being exploited if, for instance, economic downturn incentivizes cost-cutting measures at the farm. This highlights why cases of moral responsibility, such as the manager not paying overtime, are different from cases of structural injustice, of being trapped in a position vulnerable to domination without having a clear party to blame. In other words, structural injustice does not refer to actions and liabilities, but to 'relational positions of power, regardless of whether this power is exercised' (Gädeke, 2021). The system of injustice can then only be dismantled if all actors who have political responsibility fulfill it. But if there is no clearly identifiable agent to blame, who bears the political responsibility to fight injustice?

Following EUE arguments, responsibility falls on the Global North. They are in a dominating position over Global South countries, and thus they have the power and obligation to change this. Yet speaking of the Global North as one unified actor also neglects the variety of positions Global North countries have in relation to the cut-flower business. In the case of Colombian flowers, the US is by far the largest importer of flowers, meaning they likely have the leverage and capacity to fight for better practices within the business. However, commonly proposed policies such as imposing maximum residue limits or entering preferential trade agreements risks reinforcing the powerful position of the US.

Ferm (2008) and Patel-Campillo (2011) find that it is exactly those preferential trade agreements, allowing Colombia to export flowers tax-free, that are a key incentive for the

Colombian government to choose trade and growth in the flower sector, over higher wages and social security. From their perspective, the government of Colombia is not only the dominated but also the dominator. Their position of power vis-à-vis the workers means that they have a direct impact on outcomes in the industry, and thus they argue for responsibilities for the national government to enact legislation to improve working conditions.

Yet emphasizing the role of governments minimizes the responsibility for actors within the cut-flower business itself. Even managers and owners who do adhere to the law still have the political responsibility to fight injustice based on the position of power they occupy. Organizations such as Ascolflores, representing the interests of farm owners, have had high success in lobbying the government for favourable policies, showing that they do have the capacity to change practices within the industry. Gädeke (2021) even argues that female workers within the industry have some political responsibility to fight the structural injustices they face, based on the idea that structural injustice also depends on the collective actions of the women themselves. Although they are limited in their power to effectively dismantle oppressive structures, they do have the responsibility to challenge the sometimes-normalized narrative of their domination. On the other side of the supply chain, consumers of cut-flowers have political responsibility as well. Although the individual act of buying cut-flowers does not directly harm another, the act contributes to a larger system that reproduces structural injustice, indirectly limiting others to develop their capacities.

All in all, to fight injustice within the industry, pointing at the Global North alone does not suffice. For justice to be achieved, all actors participating in the cut-flower business need to fulfill their political responsibility, not just to use their own power to achieve better outcomes, but to also challenge unequal power relationships within the system – even if this means undermining one's own position. With this conception of injustice, it becomes clear that responsibility can cross borders. By participating in international trade, individual actions contribute to larger structures of oppression all over the world. Marilyn Frye (1983) explains this by referring to a birdcage. Examining only one wire does not explain why the bird is trapped, like how focusing on one actor within the cut-flower industry does not explain structural injustice, but together, all wires amount to a cage from which the bird cannot escape.

6. Conclusion

Pesticide use in the cut-flower industry of Colombia impacts women's health through multiple pathways. Through direct exposure at the farm, and indirect contact through household activities, women face increased risks associated with pesticides, including dermatological, respiratory, and reproductive issues. This study quantified part of this impact, by investigating the causal relationship between pesticide use in the cut-flower business, proxied by square kilometers of flower farmland, and medical visits for issues related to pregnancy, childbirth and the puerperium. The results show that flower farm activity is positively associated with increased medical visits for the aforementioned conditions. This suggests that pesticides could impact women beyond the borders of the farms. These health issues are not merely a physical issue, as reproductive health concerns could have severe implications for women's mental health and wellbeing.

Adopting an ecological economic standpoint, these results should be seen in a broader perspective. Following the theory of Ecologically Unequal Exchange, developments in the cut-flower business are part of the larger the pattern of Global North countries disproportionately accessing resources in the Global South. Through this, the North effectively outsources the environmental and health burden associated with its consumption pattern. The basis of these unequal outcomes are unequal power relationships, facilitated by international trade. This is also evident in the cut-flower industry.

Informed by neoclassical economic principles and recommended by international organisations such as the IMF and the World Bank, trade liberalization became a key strategy for Global South governments to achieve an export-led growth trajectory. In Colombia, this resulted in a focus on non-traditional agricultural exports, such as cut-flowers, destined for Global North markets. Growth of the cut-flower sector is on the one hand associated with the increased labour force participation of women, but on the other hand with cost-reducing strategies impacting environmental and human health to stay competitive in the flower market. As a result, on top of being disproportionately exposed to pesticides, women in the industry are also subject to exploitative working conditions which again impacts their health and wellbeing.

From a philosophical perspective, outcomes for women in the cut-flower business amount to structural injustices, whereby the oppression they experience is not the direct consequence of the act of one individual, but rather of the system as a whole. Where EUE theory argues for Global North responsibilities, based on the position of power they have over the Global South, examining power dynamics from a more critical normative angle leads to a more nuanced conclusion. Importing nations, flower consumers, Colombia's national government, managers, and even the women themselves all play a role in reproducing positions of power within the industry, and thus they all have the political responsibility to dismantle and undermine these positions. Substantiating exactly the type of obligations that follow from this could be a good avenue for future research,

Further suggestions for future research include quantifying the exact flows of resources within the cut-flower business, as the reliance on exports hints at the potential for unequal exchange. Lastly, in this study women are treated as a homogenous group, impacted equally by the cut-flower business. However, the experience of women intersects with their individual experience related to many other aspects of their identity including class, race, sexuality, and age. Previous research highlights that within the cut-flower industry, women in lower-level positions often come from different backgrounds than women in higher-level positions. Taking account intersectionality in further research could add new depth to these results.

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Appendix A – Data cleaning process

Datasets are sorted, filtered, and summed based on departmental and municipal codes provided by DANE. For Antioquia, departmental code 05, all municipalities fall in the range of 5000 to 5999 based on alphabetical order. For Cundinamarca, departmental code 25, all municipalities range from 25 000 to 25 999, also based on alphabetical order. See the supplementary data sheets for more information.

Variable: Condition O

RIPS data for the dependent variable is downloaded from the website of the Ministry of Health (minsalud). The original dataset contains with more than 11 million entries for all different types of medical visits for the year 2019, 2020, and 2021. The data filter

- After filtering for year (2019), department (Antioquia and Cundinamarca) and type of diagnosis (O), around 100 000 entries remain.
- These entries are then sorted by department and municipality. The final list of visits per department can be found in the file "Supplementary data 1"
- The classification of letters and their corresponding diagnosis type are based on the table from the supplementary material by Camacho & Meija (2017)

Chapter	Blocks	Title
I	A00–B99	Certain infectious and parasitic diseases
II	C00–C99	Neoplasms
III	D00–D89	Diseases of the blood and blood-forming organs and certain disorders involving the immune mechanism
IV	E00–E90	Endocrine, nutritional and metabolic diseases
V	F00–F99	Mental and behavioural disorders
VI	G00–G99	Diseases of the nervous system
VII-VIII	H00–H95	Diseases of the eye and ear
IX	I00–I99	Diseases of the circulatory system
X	**J00–J99**	**Diseases of the respiratory system**
XI	K00–K93	Diseases of the digestive system
XII	**L00–L99**	**Diseases of the skin and subcutaneous tissue**
XIII	M00–M99	Diseases of the musculoskeletal system and connective tissue
XIV	N00–N99	Diseases of the genitourinary system
XV	**O00–O99**	**Pregnancy, childbirth and the puerperium**
XVI	P00–P96	Certain conditions originating in the perinatal period
XVII	Q00–Q99	Congenital malformations, deformations and chromosomal abnormalities
XVIII	R00–R99	Symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified
XIX	S00–T98	Injury, poisoning and certain other consequences of external causes
XX	V01–Y98	External causes of morbidity and mortality
XXI	Z00–Z99	Factors influencing health status and contact with health services

Table 1 - Copy of the list of the diagnoses considered in the research of Camacho & Meija (in bold), for the present study only condition O diagnoses related to pregnancy, childbirth and the puerperium were used. Source: Camacho & Meija, 2017.

Variable: Km2 farms
The independent variable of interest, kilometers of flower farms, comes from a list supplied by the Ministry of Agricultura (IcA), see "Supplementary Data 2". This dataset lists individual farms and provides information on which municipality the farm is in and the size of the farm in hectares.

As this data is only available for 2010, numbers for 2019 are extrapolated based on information of land-use increase for 2016 to 2019, again reported by the IcA (see sources & data file HaFarms):

Year	**Area (ha)**	**Growth rate (annual)**
2019	8597	0,01944741
2018	8433	0,03080308
2017	8181	0,06053928
2016	7714	

Table 2 – Hectares of land per year and extrapolation of annual growth rate

From these numbers the growth from 2010 to 2019 was estimated to be 33,24%.
.
Variable: Female population, MPI, lack of healthcare access
The three dataset for the above variables are taken from data given by Colombia's bureau of statistics, DANE. All data was collected for the 2018 population census and reported at the municipal level.

Variable: Total providers.
Data on the number of healthcare providers as registered with the IPS is downloaded from the Ministry of Health database, minsalud. After downloading, the data is reported by specialization type based on codes, e.g. Code P07 – Medicina (doctor). The cleaning process is therefore as follows:
- Remove all entries of departments other than Antioquia and Cundinamarca
- Sum number of healthcare providers per municipality, based on municipal codes given by DANE.

After consolidating all datasets there was one municipality that does not appear in all of the datasets, and therefore it is removed from the data file, this concerns:
- Apulo (code: 25599)

Appendix B – Output from R

*This is a direct copy of the relevant R commands and output of the regression analysis mentioned in the paper. Comments for clarification are added in **bold**. The full R output and commands are available upon request.*

```
> cor.test(dataO$kmfarms, dataO$conditionO)

	Pearson's product-moment correlation

data: dataO$kmfarms and dataO$conditionO
t = 1.4189, df = 238, p-value = 0.1572
alternative hypothesis: true correlation is not equal to 0
95 percent confidence interval:
 -0.03545142 0.21571767
sample estimates:
 cor
0.09158965

> cor.test(log1p(dataO$kmfarms), log1p(dataO$conditionO))

	Pearson's product-moment correlation

data: log1p(dataO$kmfarms) and log1p(dataO$conditionO)
t = 6.3607, df = 238, p-value = 0.000000001019
alternative hypothesis: true correlation is not equal to 0
95 percent confidence interval:
 0.2674531 0.4844215
sample estimates:
 cor
0.3811736

> #bivariate regression, regular
> biv1 <- lm(dataO$conditionO ~ dataO$kmfarms)
> summary(biv1)

Call:
lm(formula = dataO$conditionO ~ dataO$kmfarms)

Residuals:
 Min 1Q Median 3Q Max
-13863 -3143 -2778 -1799 321831

Coefficients:
```

```
  Estimate Std. Error t value Pr(>|t|)
(Intercept) 3367.7 1430.9 2.354 0.0194 *
dataO$kmfarms 938.7 661.6 1.419 0.1572
---
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 21500 on 238 degrees of freedom
Multiple R-squared: 0.008389,	Adjusted R-squared: 0.004222
F-statistic: 2.013 on 1 and 238 DF, p-value: 0.1572

>
> #bivariate regession, log transformed
> biv2 <- lm(log1p(dataO$conditionO) ~ log1p(dataO$kmfarms))
> summary(biv2)

Call:
lm(formula = log1p(dataO$conditionO) ~ log1p(dataO$kmfarms))

Residuals:
 Min 1Q Median 3Q Max
-4.3157 -0.8441 -0.0916 0.7377 5.8768

Coefficients:
  Estimate Std. Error t value  Pr(>|t|)
(Intercept) 6.50617 0.09573 67.963 < 0.0000000000000002 ***
log1p(dataO$kmfarms) 1.13379 0.17825 6.361 0.00000000102 ***
---
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 1.388 on 238 degrees of freedom
Multiple R-squared: 0.1453,   Adjusted R-squared: 0.1417
F-statistic: 40.46 on 1 and 238 DF, p-value: 0.000000001019
```

Call: **Reported as Model 1 in the paper**

```
lm(formula = log1p(dataO$conditionO) ~ log1p(dataO$kmfarms) +
 dataO$fempop + dataO$mpi + dataO$healthaccess)

Residuals:
 Min 1Q Median 3Q Max
-4.1559 -0.7720 -0.0143 0.7711 3.4131

Coefficients:
  Estimate Std. Error t value  Pr(>|t|)
(Intercept) 6.593713534 0.244414124 26.978 < 0.0000000000000002 ***
```

log1p(dataO$kmfarms) 0.942751892 0.186347967 5.059 0.00000084912473 ***
dataO$fempop 0.000007185 0.000001002 7.170 0.00000000000965 ***
dataO$mpi -0.005328953 0.006416789 -0.830 0.407
dataO$healthaccess -0.002190226 0.020853774 -0.105 0.916

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 1.257 on 235 degrees of freedom
Multiple R-squared: 0.3077,   Adjusted R-squared: 0.2959
F-statistic: 26.11 on 4 and 235 DF, p-value: < 0.00000000000000022

>
> model6A <- lm(log1p(dataO$conditionO) ~ log1p(dataO$kmfarms) + dataO$fempop + dataO$mpi + dataO$totalproviders)
> summary(model6A)

Call:
lm(formula = log1p(dataO$conditionO) ~ log1p(dataO$kmfarms) +
 dataO$fempop + dataO$mpi + dataO$totalproviders)

Residuals:
 Min 1Q Median 3Q Max
-4.2521 -0.6357 0.0133 0.7485 2.9087

Coefficients:
   Estimate Std. Error t value Pr(>|t|)
(Intercept) 6.367583609 0.225832035 28.196 < 0.0000000000000002 ***
log1p(dataO$kmfarms) 0.800633983 0.172798360 4.633 0.00000596358982718 ***
dataO$fempop 0.000026516 0.000003197 8.293 0.00000000000000859 ***
dataO$mpi -0.003691543 0.005790123 -0.638 0.524
dataO$totalproviders -0.000683849 0.000108264 -6.316 0.00000000132642340 ***

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 1.162 on 235 degrees of freedom
Multiple R-squared: 0.4082,   Adjusted R-squared: 0.3981
F-statistic: 40.52 on 4 and 235 DF, p-value: < 0.00000000000000022

> #preferred specification seems to be 6A with totalproviders --> higher Rsquared than HaFarms plus significant coefficient
>
> **Reported as Model 2 in the paper**
> #model 7&7A, log-log transformation without population

> model7 <- lm(log1p(dataO$conditionO) ~ log1p(dataO$kmfarms) + dataO$mpi + dataO$healthaccess)
> summary(model7)

Call:
lm(formula = log1p(dataO$conditionO) ~ log1p(dataO$kmfarms) +
 dataO$mpi + dataO$healthaccess)

Residuals:
 Min 1Q Median 3Q Max
-4.3624 -0.8810 -0.0764 0.7964 5.6525

Coefficients:
 Estimate Std. Error t value Pr(>|t|)
(Intercept) 6.935789 0.264078 26.264 < 0.0000000000000002 ***
log1p(dataO$kmfarms) 0.962018 0.205268 4.687 0.0000047 ***
dataO$mpi -0.011663 0.007002 -1.666 0.0971 .
dataO$healthaccess -0.003458 0.022973 -0.151 0.8805

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 1.385 on 236 degrees of freedom
Multiple R-squared: 0.1563, Adjusted R-squared: 0.1455
F-statistic: 14.57 on 3 and 236 DF, p-value: 0.000000009741

> **Reported as Model 3 in the paper**
> model7A <- lm(log1p(dataO$conditionO) ~ log1p(dataO$kmfarms) + dataO$mpi + dataO$totalproviders)
> summary(model7A)

Call:
lm(formula = log1p(dataO$conditionO) ~ log1p(dataO$kmfarms) +
 dataO$mpi + dataO$totalproviders)

Residuals:
 Min 1Q Median 3Q Max
-4.2926 -0.8021 -0.0345 0.8150 3.6083

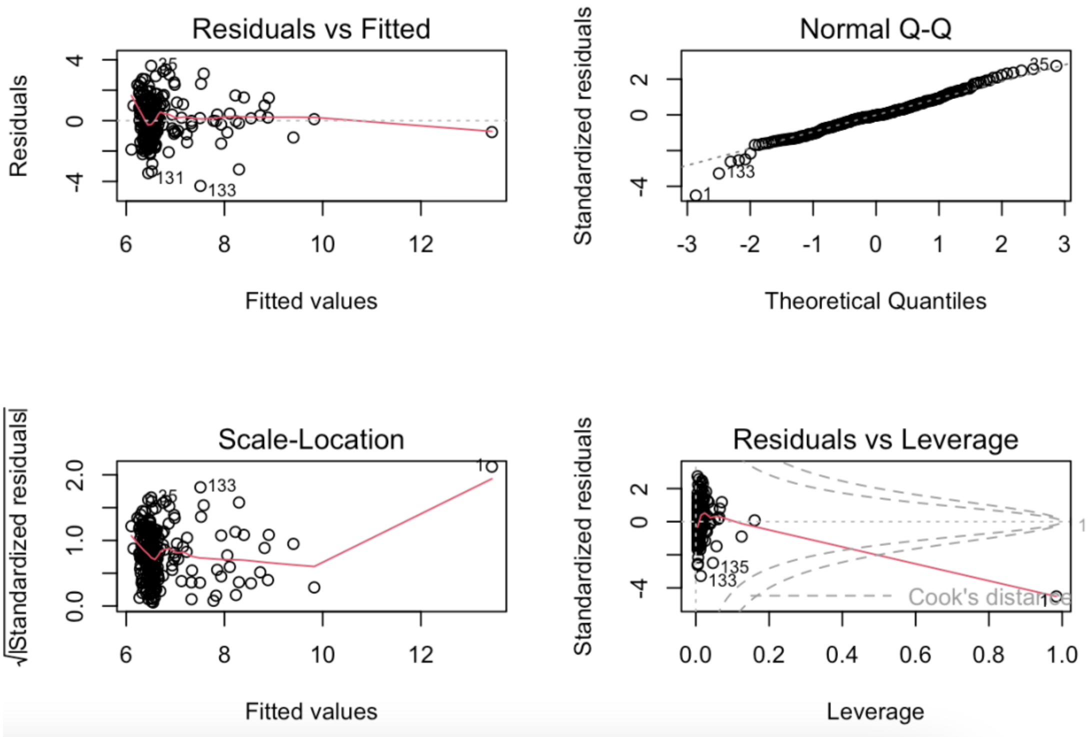
Coefficients:
 Estimate Std. Error t value Pr(>|t|)
(Intercept) 6.75182394 0.25076291 26.925 < 0.0000000000000002 ***
log1p(dataO$kmfarms) 0.98226831 0.19446397 5.051 0.000000879 ***
dataO$mpi -0.00792770 0.00654346 -1.212 0.227
dataO$totalproviders 0.00017545 0.00003559 4.930 0.000001549 ***

```
---
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 1.319 on 236 degrees of freedom
Multiple R-squared: 0.235,	Adjusted R-squared: 0.2253
F-statistic: 24.16 on 3 and 236 DF, p-value: 0.0000000000001134

> #7A is preferred over 7 (again with TotalProviders) because higher Rsquared and lower RSE, but 6A provides higher Rsquared than
> # model 7A


> #testing for heteroskedasticity: Breusch-Pagan
> library(lmtest)
Loading required package: zoo

Attaching package: 'zoo'

The following objects are masked from 'package:base':

 as.Date, as.Date.numeric

> bptest(model6)

	studentized Breusch-Pagan test

data: model6
BP = 11.747, df = 4, p-value = 0.01933

> bptest(model6A)

	studentized Breusch-Pagan test

data: model6A
BP = 43.776, df = 4, p-value = 0.000000007142

> bptest(model7)

	studentized Breusch-Pagan test

data: model7
BP = 0.44083, df = 3, p-value = 0.9317

> bptest(model7A)
```

studentized Breusch-Pagan test

data: model7A
BP = 0.38803, df = 3, p-value = 0.9427

> #finding; heteroskedasticity in both model 6's, but when population is removed (7's) no more
>
> #testing for heteroskedasticity: plot residuals of preferred model (7A)
> par(mfrow=c(2,2))
> plot(model7A)
Warning messages:
1: In sqrt(crit * p * (1 - hh)/hh) : NaNs produced
2: In sqrt(crit * p * (1 - hh)/hh) : NaNs produced



> #finding; clear outlier (probably Medellin)
>
> #robustness check; manually removing outlier Medellin
> data1 <- thesisdata[thesisdata$code>5001,c("kmfarms", "hafarms", "percentagefarms", "mpi", "conditionO", "population", "fempop", "prevalenceO", "healthaccess", "totalproviders")]
> View(data1)
> model7A1 <- lm(log1p(data1$conditionO) ~ log1p(data1$kmfarms) + data1$mpi + data1$totalproviders)
> summary(model7A1)

```
Call:
lm(formula = log1p(data1$conditionO) ~ log1p(data1$kmfarms) +
 data1$mpi + data1$totalproviders)

Residuals:
 Min 1Q Median 3Q Max
-4.1602 -0.7527 0.0330 0.7158 3.3806

Coefficients:
  Estimate Std. Error t value  Pr(>|t|)
(Intercept) 6.4289763 0.2497596 25.741 < 0.0000000000000002 ***
log1p(data1$kmfarms) 0.9005561 0.1870699 4.814  0.000002649 ***
data1$mpi -0.0009533 0.0064398 -0.148  0.882
data1$totalproviders 0.0014281 0.0002678 5.332  0.000000228 ***
---
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 1.263 on 235 degrees of freedom
Multiple R-squared: 0.2511,   Adjusted R-squared: 0.2415
F-statistic: 26.26 on 3 and 235 DF, p-value: 0.00000000000001096

> bptest(model7A1)

	studentized Breusch-Pagan test

data: model7A1
BP = 36.202, df = 3, p-value = 0.00000006786

>
> data2 <- data1[-c(18, 46, 86), c("kmfarms", "hafarms", "percentagefarms", "mpi", "conditionO", "population", "fempop", "prevalenceO", "healthaccess", "totalproviders")]
> View(data2)
> model7A2 <- lm(log1p(data2$conditionO) ~ log1p(data2$kmfarms) + data2$mpi + data2$totalproviders)
> summary(model7A2)

Call:
lm(formula = log1p(data2$conditionO) ~ log1p(data2$kmfarms) +
 data2$mpi + data2$totalproviders)

Residuals:
 Min 1Q Median 3Q Max
-3.6132 -0.7488 0.0871 0.7247 2.7977
```

```
Coefficients:
   Estimate Std. Error t value  Pr(>|t|)
(Intercept)  6.1807617 0.2371341 26.064 < 0.0000000000000002 ***
log1p(data2$kmfarms) 0.5951126 0.1783430 3.337  0.000987 ***
data2$mpi 0.0039075 0.0060769 0.643  0.520853
data2$totalproviders 0.0041737 0.0005009 8.333 0.00000000000000694 ***
---
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 1.16 on 232 degrees of freedom
Multiple R-squared: 0.3591,   Adjusted R-squared: 0.3508
F-statistic: 43.33 on 3 and 232 DF, p-value: < 0.00000000000000022

> bptest(model7A2)

        studentized Breusch-Pagan test

data: model7A2
BP = 14.343, df = 3, p-value = 0.002473

> #removed all outliers but now heteroskedastic
>
> #running robust regression
> library(MASS)
> model7A2rob <- rlm(log1p(data2$conditionO) ~ log1p(data2$kmfarms) + data2$mpi +
data2$totalproviders)
> summary(model7A2rob)

Call: rlm(formula = log1p(data2$conditionO) ~ log1p(data2$kmfarms) +
 data2$mpi + data2$totalproviders)
Residuals:
 Min 1Q Median 3Q Max
-4.01760 -0.77075 0.03917 0.67001 2.72125

Coefficients:
   Value Std. Error t value
(Intercept) 6.1742 0.2392 25.8098
log1p(data2$kmfarms) 0.7008 0.1799 3.8952
data2$mpi  0.0041 0.0061 0.6650
data2$totalproviders 0.0045 0.0005 8.8976

Residual standard error: 1.002 on 232 degrees of freedom
> summary(model7A2rob)$sigma
[1] 1.002267
```

```
> summary(model7A)$sigma
[1] 1.318632
> #finding; Rsquared slightly higher, RSE slightly lower, but now heteroskedastic
>
> #run robust regression
> library(robustbase)
> model7A1rob <- lmrob(log1p(data1$conditionO) ~ log1p(data1$kmfarms) + data1$mpi +
data1$totalproviders)
> summary(model7A1rob)

Call:
lmrob(formula = log1p(data1$conditionO) ~ log1p(data1$kmfarms) + data1$mpi +
 data1$totalproviders)
 \--> method = "MM"
Residuals:
 Min 1Q Median 3Q Max
-15.99763 -0.79690 0.03194 0.63467 2.64315

Coefficients:
   Estimate Std. Error t value  Pr(>|t|)
(Intercept)  6.122299 0.284934 21.487 < 0.0000000000000002 ***
log1p(data1$kmfarms) 0.720977 0.121942 5.912  0.0000000118 ***
data1$mpi 0.005403 0.007910 0.683  0.495
data1$totalproviders 0.004840 0.001196 4.047  0.0000704027 ***
---
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Robust residual standard error: 1.077
Multiple R-squared: 0.3908,   Adjusted R-squared: 0.383
Convergence in 20 IRWLS iterations

Robustness weights:
 3 observations c(18,46,86) are outliers with |weight| = 0 ( < 0.00042);
 25 weights are ~= 1. The remaining 211 ones are summarized as
 Min. 1st Qu. Median Mean 3rd Qu. Max.
0.05117 0.86000 0.95120 0.89360 0.98540 0.99870
Algorithmic parameters:
 tuning.chi  bb tuning.psi refine.tol rel.tol  scale.tol  solve.tol
 1.547640000000    0.500000000000    4.685061000000    0.000000100000    0.000000100000
0.000000000100 0.000000100000
 eps.outlier  eps.x warn.limit.reject warn.limit.meanrw
 0.000418410042 0.000000006501 0.500000000000 0.500000000000
 nResample  max.it best.r.s k.fast.s  k.max maxit.scale trace.lev mts compute.rd
 500  50  2  1 200 200  0 1000  0
```

```
fast.s.large.n
  2000
  psi subsampling  cov compute.outlier.stats
 "bisquare"  "nonsingular"  ".vcov.avar1"  "SM"
seed : int(0)
> bptest(model7A1rob)

	studentized Breusch-Pagan test

data: model7A1rob
BP = 36.202, df = 3, p-value = 0.00000006786



> #only with farm activity
> datafarms <- thesisdata[thesisdata$hafarms>0,c("kmfarms", "hafarms", "percentagefarms", "mpi", "conditionO", "population", "fempop", "prevalenceO", "healthaccess", "totalproviders")]
> View(datafarms)
> model9 <- lm(log1p(datafarms$conditionO) ~ log1p(datafarms$kmfarms) + datafarms$mpi + datafarms$totalproviders)
> summary(model9)
```

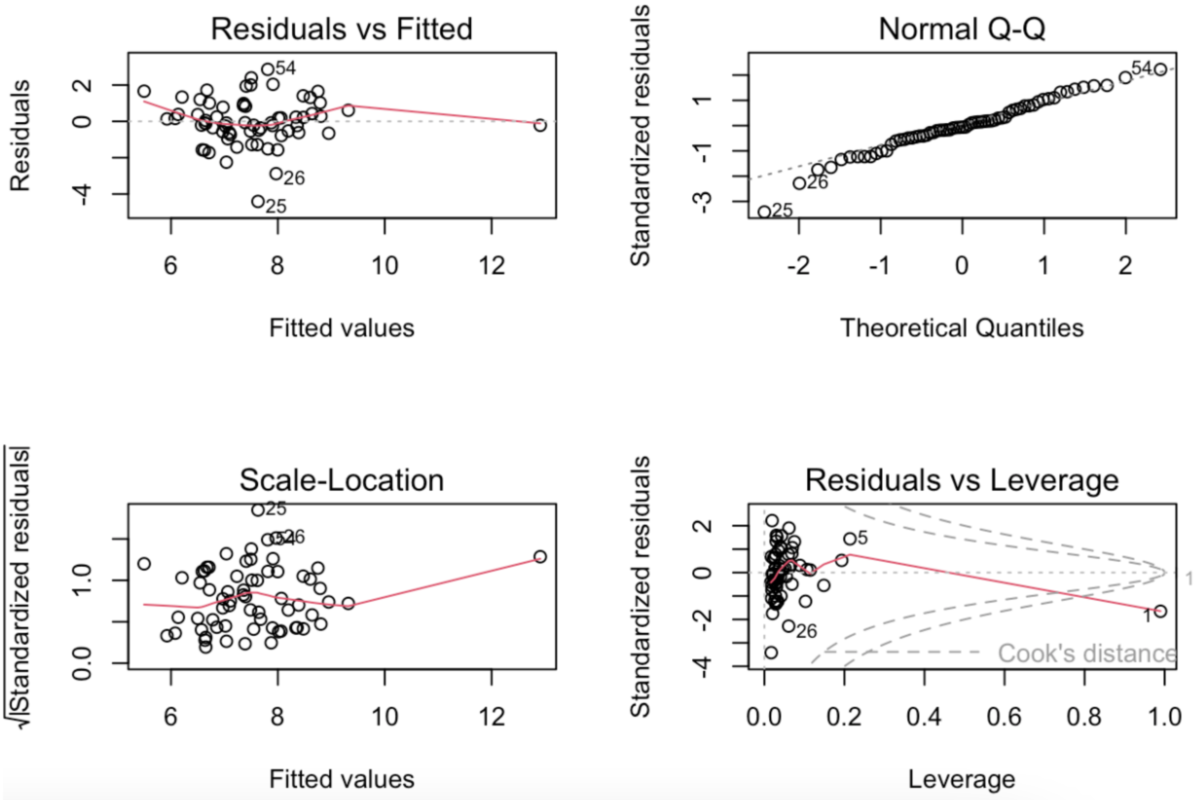
Call: **Reported as Model 5 in the paper**

```
lm(formula = log1p(datafarms$conditionO) ~ log1p(datafarms$kmfarms) +
 datafarms$mpi + datafarms$totalproviders)

Residuals:
 Min 1Q Median 3Q Max
-4.4091 -0.6194 -0.0782 0.8283 2.8611

Coefficients:
  Estimate Std. Error t value  Pr(>|t|)
(Intercept)  7.80203246 0.50766568 15.368 < 0.0000000000000002 ***
log1p(datafarms$kmfarms) 0.60715492 0.25157930 2.413  0.018824 *
datafarms$mpi -0.04323592 0.01891593 -2.286  0.025761 *
datafarms$totalproviders 0.00014774 0.00003589 4.117  0.000117 ***
---
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 1.301 on 61 degrees of freedom
Multiple R-squared: 0.4113,   Adjusted R-squared: 0.3824
F-statistic: 14.21 on 3 and 61 DF, p-value: 0.0000003964

> bptest(model9)
```

studentized Breusch-Pagan test

data: model9
BP = 0.46474, df = 3, p-value = 0.9266

> #finding: no heteroskedasticity
>
> #visualize, result; still seeming outlier (Medellin)
> par(mfrow=c(2,2))
> plot(model9)



Warning messages:
1: In sqrt(crit * p * (1 - hh)/hh) : NaNs produced
2: In sqrt(crit * p * (1 - hh)/hh) : NaNs produced
> datafarms_noM <- datafarms[datafarms$population<2000000, c("kmfarms", "hafarms", "percentagefarms", "mpi", "conditionO", "population", "fempop", "prevalenceO", "healthaccess", "totalproviders")]
> View(datafarms_noM)
> #run same model, now only with farm activity excluding Medellin
> model10 <- lm(log1p(datafarms_noM$conditionO) ~ log1p(datafarms_noM$kmfarms) + datafarms_noM$mpi + datafarms_noM$totalproviders)

```
> summary(model10)
```

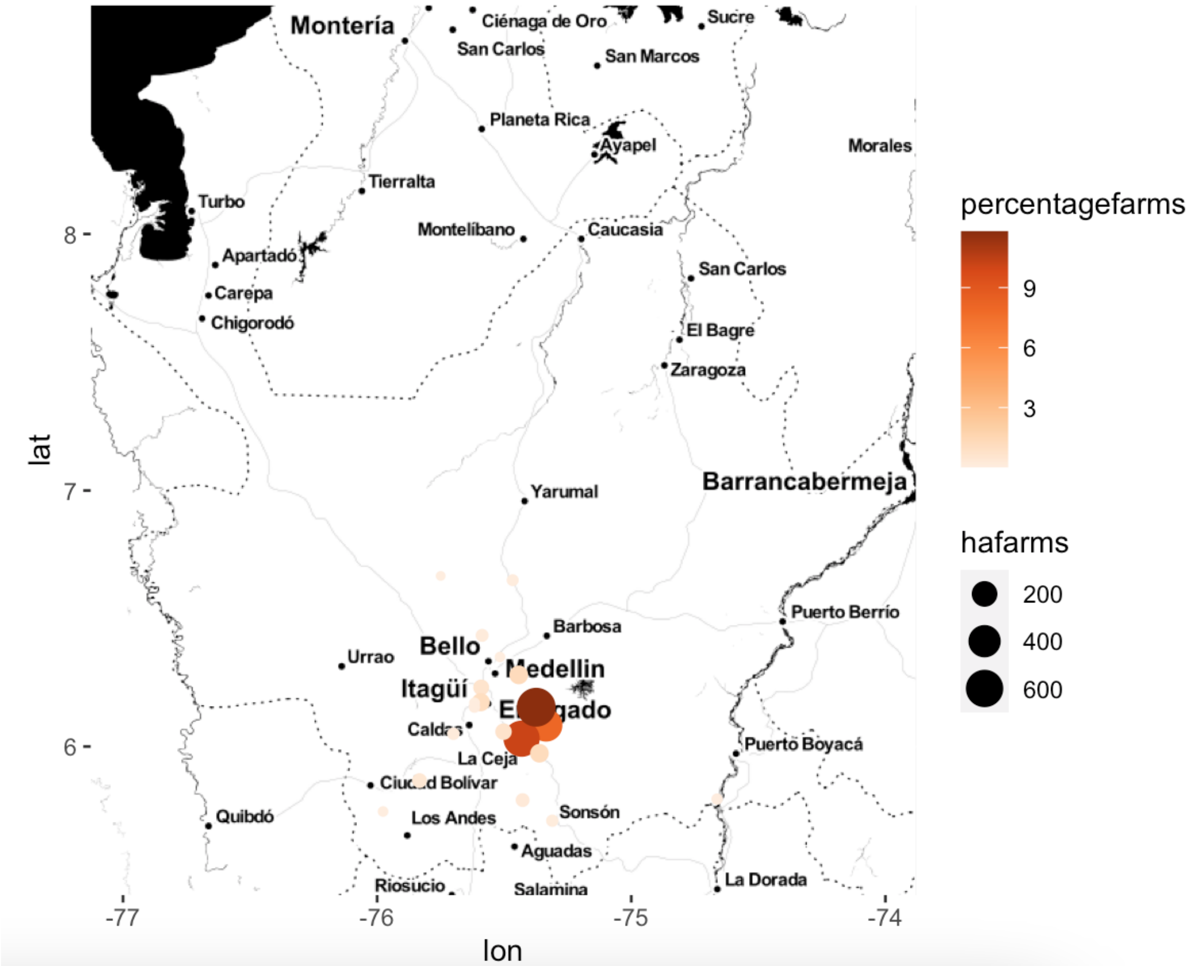
Call: **Reported as Model 6 in the paper**

```
lm(formula = log1p(datafarms_noM$conditionO) ~ log1p(datafarms_noM$kmfarms) +
 datafarms_noM$mpi + datafarms_noM$totalproviders)

Residuals:
 Min 1Q Median 3Q Max
-4.2659 -0.4816 -0.0023 0.9059 2.4970

Coefficients:
   Estimate Std. Error t value  Pr(>|t|)
(Intercept)  7.3478299 0.5689345 12.915 < 0.0000000000000002 ***
log1p(datafarms_noM$kmfarms) 0.6709650 0.2508304 2.675  0.00962 **
datafarms_noM$mpi -0.0285451 0.0205980 -1.386  0.17093
datafarms_noM$totalproviders 0.0007190 0.0003425 2.099  0.04004 *
---
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 1.282 on 60 degrees of freedom
Multiple R-squared: 0.3349,   Adjusted R-squared: 0.3017
F-statistic: 10.07 on 3 and 60 DF, p-value: 0.00001812

> bptest(model10)

	studentized Breusch-Pagan test

data: model10
BP = 3.5358, df = 3, p-value = 0.3161
```

Visualizing geodata

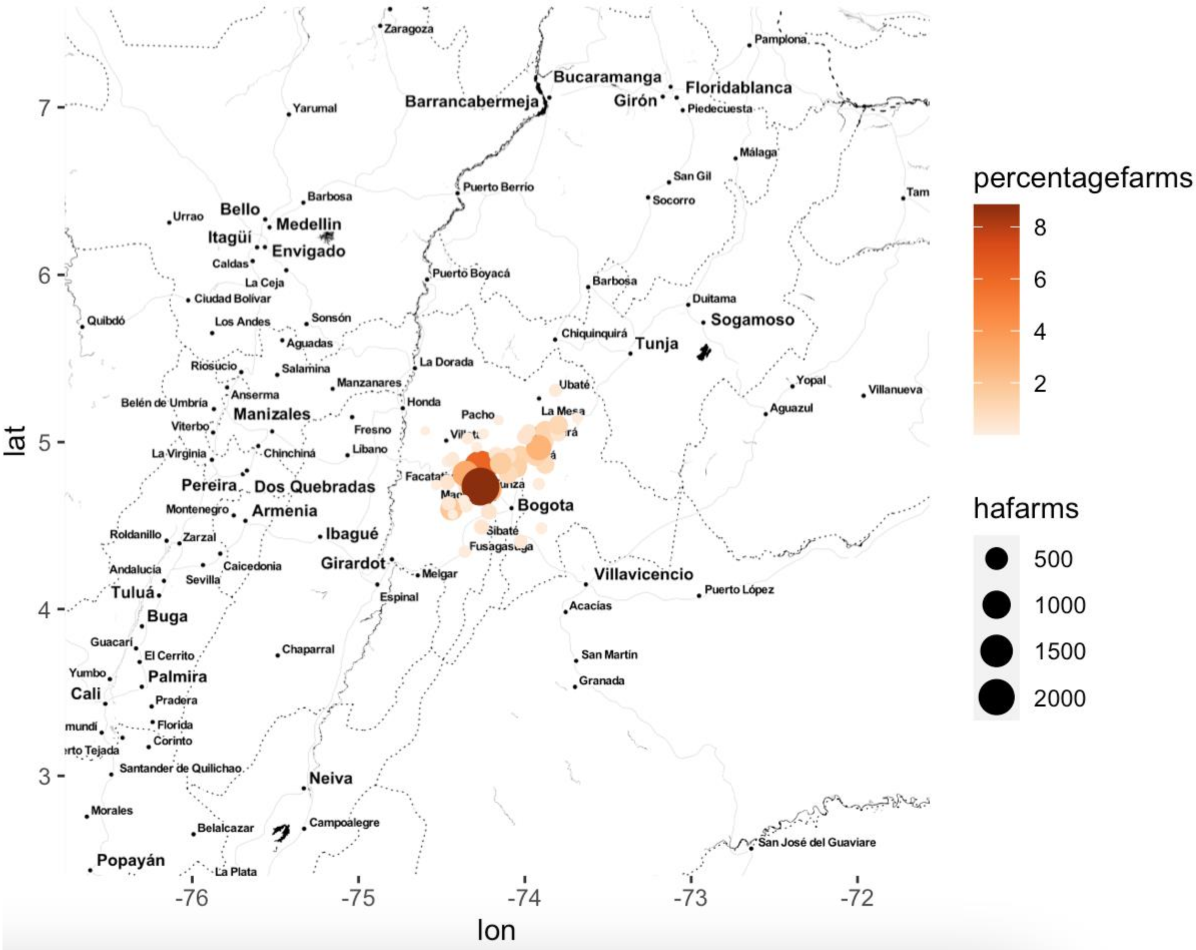
```
> library(readxl)
> geodata_a <- read_excel("~/Desktop/R/Projects/thesis/thesis/thesisdata.xlsx", sheet = "geomap_a")
> View(geodata_a)
> geodata_c <- read_excel("~/Desktop/R/Projects/thesis/thesis/thesisdata.xlsx", sheet = "geomap_c")
> View(geodata_c)
> library(ggplot2)
> library(ggmap)
ℹ Google's Terms of Service: <https://mapsplatform.google.com>
ℹ Please cite ggmap if you use it! Use `citation("ggmap")` for details.
```

> library(tidyr)
> library(osmdata)
Data (c) OpenStreetMap contributors, ODbL 1.0. https://www.openstreetmap.org/copyright
>
> antioquia_map <- get_map(getbb('Antioquia'), source = "stamen", maptype = "toner", zoom = 8)
ℹ Map tiles by Stamen Design, under CC BY 3.0. Data by OpenStreetMap, under ODbL.
> ggmap(antioquia_map) +
+ geom_point(data = geodata_a, mapping = aes(x = longitude, y = latitude,
+   col = percentagefarms, size = hafarms)) +
+ scale_color_distiller(palette = "Oranges", direction = 1)
Warning message:
Removed 1 rows containing missing values (`geom_point()`).
>
> geodata_c <- read_excel("~/Desktop/R/Projects/thesis/thesis/thesisdata.xlsx", sheet = "geomap_c")
> View(geodata_c)

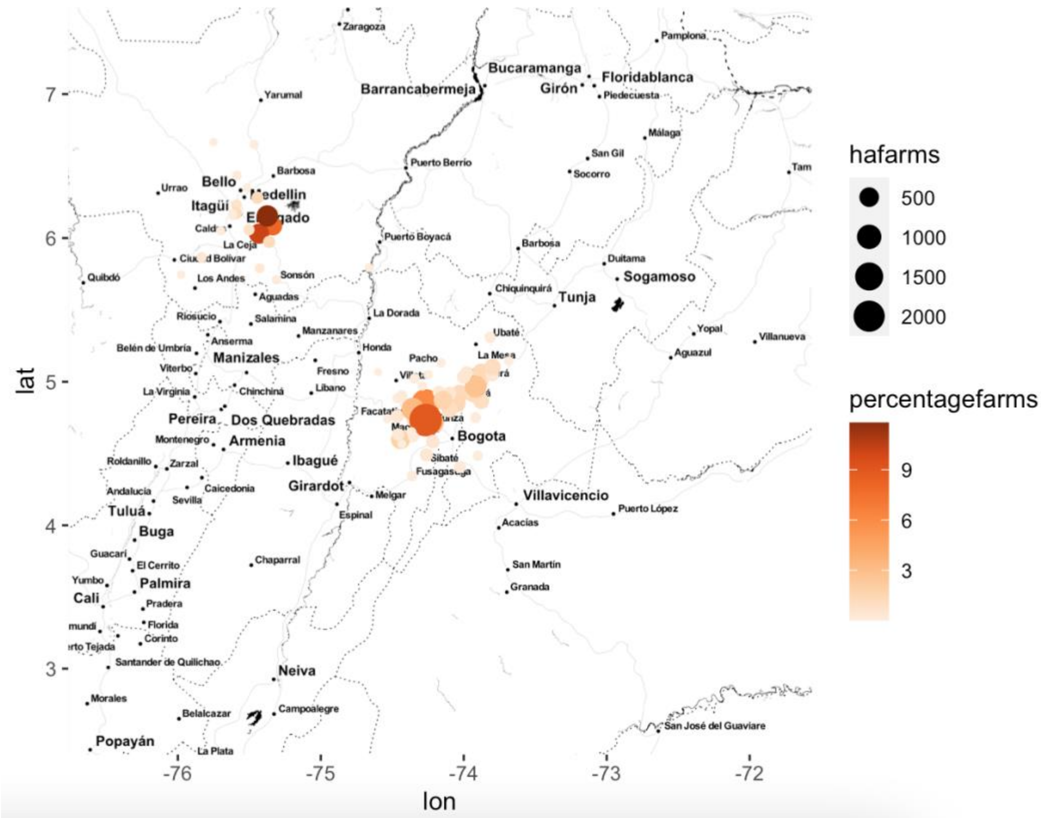


>
> cundinamarca_map <- get_map(getbb('Cundinamarca'), source = "stamen", maptype = "toner", zoom = 8)

```
ℹ Map tiles by Stamen Design, under CC BY 3.0. Data by OpenStreetMap, under ODbL.
> ggmap(cundinamarca_map) +
+ geom_point(data = geodata_c, mapping = aes(x = longitude, y = latitude,
+    col = percentagefarms, size = hafarms)) +
+ scale_color_distiller(palette = "Oranges", direction = 1)
```




```
>
> cundinamarca_map <- get_map( getbb('Cundinamarca'), source = "stamen", maptype = "toner", zoom = 8)
ℹ Map tiles by Stamen Design, under CC BY 3.0. Data by OpenStreetMap, under ODbL.
> ggmap(cundinamarca_map) +
+ geom_point(data = geodata, mapping = aes(x = longitude, y = latitude,
+     col = percentagefarms, size = hafarms)) +
+ scale_color_distiller(palette = "Oranges", direction = 1)
Warning message:
Removed 1 rows containing missing values (`geom_point()`).
```



hafarms
500
1000
1500
2000
percentagefarms
9
6
3
lat
lon
-76
-75
-74
-73
-72
7
6
5
4
3
Medellín
Bogota
Bucaramanga
Barrancabermeja
Floridablanca
Girón
Manizales
Pereira
Dos Quebradas
Armenia
Ibagué
Girardot
Villavicencio
Tunja
Sogamoso
Tuluá
Buga
Palmira
Cali
Neiva
Popayán
Bello
Itagüí