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Crofils, Cédric Pierre Sylvain

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The effects of Rising Temperatures on Migration in Indonesia

Crofils, Cédric Pierre

Comisión EH ClioLab

Jeanne Lafortune
Jose Díaz

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The effects of Rising Temperatures on Migration in Indonesia

Cedric Crofils

Instituto de Economía, Pontificia Universidad Catolica de Chile

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Under the supervision of Jeanne Lafortune, Jose Díaz and the members of the EH ClioLab.[1]

Abstract

This study aims to present the impact of climate change, as proxied by increased temperatures, on migration, through its adverse effects on agriculture, in Indonesia, a developing country. Using a micro-level approach, we find that there is indeed an effect of rising temperatures on migration for the farmers, but not on the urbanization rates. We conclude that the farmers tend to leave their farm with higher temperatures, but do not necessarily go to urban areas, challenging the recent literature on the subject.

[1]This thesis was made during the "Seminario de Tesis del Clio-Lab" of the Magister of Economics of the Pontificia Universidad Catolica de Chile. I would like to thank my supervisors, Professors Jeanne Lafortune and Jose Díaz for their help, support and comments along the redaction of this work. I also would like to thank the members of the EH ClioLab, Professors Felipe Aldunate, José Tessada, Francisco Gallego, Felipe González, Rolf Luders y Gert Wagner for their help and comments, along with Isaac Martinez, León F. Guzmán and Professor Stephanie Monjon for their technical help and recommendations. Finally, I thank my family and my friends for their constant support.

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1 Introduction

One of the major concern of the international community is the effect of Climate Change on our societies. Global Warming is expected to manifest itself in several ways. One is the variation in the climatic conditions. Indeed, the scientific community forecast, inter alia, an increase in "the global mean surface air temperature in the range 0.3 to 0.7 C" and an increase in the mean precipitations in the near-term (before 2035)[1]. They also expect more frequent warm days and warm nights, as well as an increased "frequency and intensity of heavy precipitation events over land"[1]. These events may affect more the countries of the Southern Hemisphere, given that most of them are located between the tropics, where the impacts of climate change are expected to be higher and more likely negative compared to the Northern Hemisphere. Indeed, as stated in Chapter 11 of the IPCC, Working Group 1, "increases in seasonal mean and annual mean temperatures are expected to be larger in the tropics and subtropics than in mid-latitudes". As most of the developing countries are located in the southern hemisphere, we might expect that climate change will be a critical challenge to overcome, added to the current challenges of development and poverty alleviation of these countries.

One can focus more on the effects of climate change on agriculture. Indeed, the events previously stated will have a significant impact on crop yields. According to the scientific community, "for the major crop in tropical and temperate regions, climate change without adaptation will negatively impact production for local temperature increases"[2]. As the crop yields decrease, the farmers' wages are expected to drop too. Given that, in developing countries, a large part of the population is rural and still highly rely on agricultural production, climate change is, therefore, a critical issue, as it threatens both income and food security.

These events will have the effect to raise the food prices and make these vulnerable populations even more exposed to the climate risk. We shall remember that, as these farmers are located in rural (and sometimes remote) areas and as many of them are poor, they lack a proper access to financial institutions, which could have helped them to prepare the climate changes and smooth their consumption. We can see here why climate change may negatively affect the livelihood of the rural population through the agriculture.

Given these facts, farmers in developing countries have a strong need for adaptation. Many ways of adaptation for the agricultural issues exist and have been documented by the scientific community (See IPCC, Working Group II, 9.4.3.1). Nevertheless, one important solution to take into account is migration, as it might change the demographic equilibrium of the developing countries. The farmers could have an incentive to leave the countryside (by selling their land if they owned it while it still has some value) and to emigrate from the rural areas. Seeing that their revenues are decreasing, they can choose to go to a bigger city, where they are more likely to find a job, or to go to another country to find other opportunities. Given that not everybody has the means to migrate, this hypothesis would concern

[1]IPCC, Working Group I, Chapter 11, p. 955-956

[2]IPCC, Working Group II, Chapter 7, p. 488

especially the relatively richer people (or the ones who have more skills) whereas the others would stay, and eventually buy the remaining land for a lower price.

C. Cattaneo and G. Peri (2015) showed that this hypothesis is true for middle-income countries. In those countries, farmers have enough liquidity to migrate and have an incentive to do it before losing too much because of climate change. Climate change has there the effect of lowering the barriers to migration, as the costs of migration are compensated by the potential higher cost of staying in the area. On the contrary, in poor countries, farmers are restrained by their budget constraints and locked into a poverty trap, which prevents them from migrating. With a macro-level approach with a large panel of countries, the study focused on international migration and on urbanization. It, therefore, separates the rich, middle income and poor countries.

I propose here to check if the main result remains valid, but using a micro-level approach to take into account the additional incentive created by the agricultural productivity loss. Indeed, it could be interesting as well to see whether this finding remains accurate for internal migration - migration within the same country - and urbanization, meaning the move from a rural area to a more developed and urban area. Moreover, as intra-national migration implies much lower moving costs than international migration, it could be interesting to see whether the migration response found by Cattaneo and Peri (2015), is in fact, higher than expected or not. Using a micro-level approach is interesting because the credit constraints will tend to be less biding than for international migration, but the individuals are less likely to escape from climate change, given that it has impacts across the whole country. We can use the case of Indonesia, a middle-income country located in the southern hemisphere, which is a great example to test this theory, given some of its characteristics. As Indonesia is an archipelago, it is vulnerable to the impacts of climate change. Annual mean temperature has already risen by 0.3° C between 1990 and 2007 and is expected to still increase, as well as the precipitations. With 14% of its GDP coming from the agricultural sector, Indonesia is a major agricultural producer of South-East Asia. Around one-third of the population is employed in agriculture. The sector is therefore important for the country, and its vulnerability toward climate change may affect a large part of the population in the near future.

The idea of this study is to isolate the long-term effect of the gradual rise of temperature on migration, through its adverse impact on agriculture. We will not take into account the other factors related to climate change that could motivate the individuals to migrate (like short-term migration due to a strong and violent natural disaster, or a disease,...). To simplify the model, we also will not focus on the effect of rising prices (due to the fall of the offer), which will affect the real wage of the farmers. We will concentrate instead on the migration due to the fall of agricultural yield, leaning on the rise of the temperature and the precipitation's volatility. As we occult many drivers that can exacerbate the effect of climate change on migration, this study aims to provide a lower bound of the actual migration response to the overall manifestations of climate change. To model the migration decision, we will rely on the Roy-Borjas model, extended to a one-period framework with the addition of the climate change effect. Then, to study the two combined phenomena (ie. climate change and agriculture), we will use both a data panel method and the difference-in-difference method.

We find that the results for migration overall are consistent with the findings of Cattaneo and Peri (2015), meaning that there is effectively an impact of climate change on migration for the farmers in Indonesia. The different regressions made show significantly that the farmers tend to migrate with rising temperatures, while it is not necessarily the case for the non-farmers. However, we find distinct results for the urbanization patterns. Indeed, there is no evidence that rising temperatures increase the urbanization rate, unlike the results of Cattaneo and Peri (2015).

The rest of this thesis is organized as follows. In Section 2, I review the literature associated with the subject. In Section 3, we will develop the theoretical framework used to model the migration decision. Section 4 makes a description of Indonesia and the data, with some descriptive statistics. Section 5 will present the empirical model used and Section 6 the results. Section 7 will conclude.

2 Literature Review

The design of this research rests on several previous results.

As we emphasize on the effects on agriculture, we will first present the evidence that climate change has an impact on agricultural production. The study of Hertel and Rosch (2010) stressed out the link between climate change, agriculture, and poverty. Using different simulation models, they showed that, without price changes, climate change would reduce farm earnings, given its adverse impact on productivity. If the prices are included in the model, then the effect depends on the demand elasticity and on the scope of the climate shock. Using the example of India, Guiteras (2007) found a similar result, showing negative impacts of predicted climate change over major crop yields in the medium term and even more negative in the long term in the absence of adaptation from the farmers.

The Chapter 7 of the IPCC (Working Group II) presents some papers on the correlation between increasing temperatures and crop yields. We can learn that this relationship is "often crop and region specific"[3]. Emphasizing this, A. Candradijaya & al. (2014), who showed that climate change is having an adverse effect on crop yield in the region of West Java in Indonesia. Their General Circulation Model (GCM) also demonstrates that climate change (including changes in temperatures and precipitations) will, in the near future, negatively impact the rice yield, which is an important crop food in Indonesia. Thus, we have sufficient evidence to believe that agricultural productivity in Indonesia will be negatively impacted by climate change. Will this negative impact on agriculture lead to more migration?

Many studies focus on the effect of natural disasters on migration. V. Mueller, C. Gray, and K. Kosec (2014) studied the effect of heat stress flooding on the migration in rural Pakistan and found that heat stress indeed increase long-term migration. C. Gray and V. Muller (2012) made the same exercise for the effect of flooding and crop failure in rural Bangladesh. C. Gray and R. Bilsborrow (2013) focused on the effect of environmental conditions, such as weather shocks on mobility in rural Ecuador. They found mixed results. However, as we want to emphasize on the long-term permanent migration, migration due to punctual climatic catastrophes may not capture the effect we want to show. We will focus instead on the literature that emphasizes on the rise of temperatures and the volatility of precipitation. One publication close to my study is the paper of Bohra-Mishra & al. (2014). With a micro-level approach, they focused on the permanent migration response to climate change in Indonesia, measured by both changes in temperatures and precipitations, and natural disasters. Using also the IFLS data, they found that rising temperatures are the main factor that motivates permanent migration. Precipitations have also an importance, given the correlation with the temperatures. Natural disasters have a lesser incidence concerning the long-term (permanent) migration. My study differs from theirs in that I emphasize here on the effect on agriculture, by focusing on the migration of farmers.

One other paper that has looked at the relationship between temperatures and migration is that of Cattaneo & Peri (2015). Using a macro-level approach, they

[3] IPCC, Working Group II, Chapter 7 (2014), page 497

measured the migration response of increasing temperatures over a large panel of countries. They find that in middle-income countries, farmers are rich enough to migrate and have an incentive to do it before losing too much because of climate change. Climate change has there the effect of lowering the barriers to migration, as the costs of migration are compensated by the potential higher cost of staying in the area. In poor countries, it has the reverse effect, given that the farmers are restrained by their budget constraints and locked into a poverty trap.

The aim of this research is therefore to complement the two precedent studies. Indeed, the first uses a micro-level approach to study the effect of climate change on the overall permanent migration, but it does not emphasize with agriculture specifically. The second identifies the role that plays agriculture in the effect of increasing temperatures on migration, but with a macro-level approach that uses international aggregates, which may not reflect the diversity of the agents' choices. What we want to do here is focus only on the agriculture channel but with a micro-level approach to see whether there is an actual link between climate change, agriculture, and migration.

3 Theoretical Framework

3.1 Microeconomic analysis

To better understand how climate may affect migration decision, we use a one-period model to simulate the decision process. Here, the agents have the choice between Stay (and earn a wage w_S) or Leave (and earn w_L). Leave includes both migrations within and outside the country. To migrate, agents will have to support moving costs, C^i. We assume that, before any climate change shock, the unemployment was at its natural rate. Hence, each agent has to choose between :

$$\begin{cases} w_S^i & \text{if he stays} \\ w_L^i - C^i & \text{if he leaves} \end{cases} \tag{1}$$

We now introduce the Roy-Borjas model (modified as in Cattaneo and Peri), which consists in express the wage distribution as :

$$w_{j,t}^i = \mu_{j,t} + \beta_j \epsilon_t^i \tag{2}$$

where :

- $\mu_{j,t}$ can be viewed as the basic income level at time t in location j.
- β_j is the return to skill in location j.
- ϵ_t^i is the individual error, which can be viewed as the level of skill of the agent (its methods of agriculture, its education, the amount of time and efforts involved in the activity...).

Replacing equation (2) in the choice (1), we find that agents will move if :

$$w_L^i - C^i \geq w_S^i \tag{3}$$
$$\Leftrightarrow w_L^i - w_S^i \geq C^i \tag{4}$$
$$\Leftrightarrow \mu_L + \beta_L \epsilon^i - \mu_S - \beta_S \epsilon^i \geq C^i \tag{5}$$
$$\Leftrightarrow \mu_L - \mu_S + (\beta_L - \beta_S)\epsilon^i \geq C^i \tag{6}$$
$$\Leftrightarrow \epsilon^i \geq \frac{\mu_S - \mu_L + C^i}{\beta_L - \beta_S} \tag{7}$$

We find the lower level of skills for which the agents have an incentive to migrate.

We assume here that the basic income in the location of origin is lower than the one of the location of destination (that is $\mu_L \geq \mu_S$), which explains why the cost of migration is positive, and so is the threshold. This threshold is pondered by the difference of return of skill between the location of destination and the one of origin $(\beta_L - \beta_S)$.

We now introduce climate change in this model. We assume that the rise of temperatures negatively impacts the basic income level in the location of origin: $\mu_S = \mu_S(Temp_t)$ where $Temp_t$ measure the climate conditions (temperature and precipitations) and μ_S is a decreasing function. However, in the location of destination, we suppose that the basic income level is not correlated with the climate change (or at least that the correlation is not relevant enough). Indeed, in the location of origin, we suppose that agriculture is the main sector of activity and therefore the productivity (and the wages) are highly impacted by the temperatures. On the contrary, in the location of destination, we suppose that the individuals will migrate to find jobs less related to agriculture. Therefore, in those areas, the temperatures do not affect that much the wages. Hence, μ_L would not move.

With this assumption, we can update the threshold found in (7) with :

$$\epsilon^i \geq \frac{\mu_S(Temp_t) - \mu_L + C^i}{\beta_L - \beta_S} \tag{8}$$

As Cattaneo and Peri (2015), we find that, as the temperatures increase, the basic income level would be lower (μ_S decreases) and therefore the threshold would tend to decrease. This implies that the minimum level of skills that gives an incentive to migrate is even lower, so more people would leave their lands if temperatures rise.

For the people that are below the threshold (8), the incentive to migrate is not strong enough. It can be because they lack skills that could be useful in another area, or because the cost of migration is too high. Either way, they would prefer to stay in the same area for now. Therefore, they could be the ones who buy the land from the leaving households, because the land has now a lower value and the migrants need liquidity to leave the area.

The model presented above can be summarized the following way:

- Individuals that have a level of skill above the threshold (8) have an incentive to migrate to an area where the impact of climate change is less important.
- The ones below the threshold will not migrate, either because they lack skills or because of the too high cost of migration.
- The threshold (8) is decreasing with the rise of the temperature, meaning that more people will have an incentive to migrate if the temperature rises.

3.2 General Equilibrium Analysis

Given these population's displacements, one could think about the equilibrium between the offer and the supply on the labor market and the effects on the wages. We will provide here some explanation to understand why the model is consistent with a macroeconomic analysis as well. We shall remember first that, in Indonesia, the secondary and tertiary sectors' shares of GDP are growing and are generally present in the urban areas. Also, we might recall that one expected effect of climate change is a rise in the food prices.

We use a simple Keynesian model and define $N_j^D = N^D(\frac{W_j}{P})$ and $N_j^S = N^S(\frac{W_j}{P})$ the labor demand and supply in the area $j = S, L$. Without loss of generality, we assume here that the prices, P, (or at least the variation in the prices) are the same in both areas. N_j^D is the demand for labor, decreasing with the real wage $w_j = \frac{W_j}{P}$, while the offer for labor N_j^S is increasing with the real wage. The production, Y^j, is increasing with the labor level. Climate change is here the shock that will affect the economy.

In the locality of origin, we assume that the production Y^S is decreasing, due to the fall of crop yield, which we can assimilate to a drop in productivity. This decrease of the production leads to a fall in the nominal wages, W_S. In addition to that, we assume that the prices are rising, also due to the decrease of the offer on the goods market. Hence, we observe a decrease of the real wage $w_S = \frac{W_S}{P}$, due to the simultaneous fall of W_S and rise of P. As the labor demand decreases, we obtain also a fall in the labor offer in the area of origin, in order to maintain the equilibrium. This fall of labor supply will correspond in our model to more migration from the rural areas.

In the locality of destination, the problem is different. Indeed, we shall distinguish the urban destinations from the rural ones, given that migration does not necessarily lead to urbanization. In urban areas, we assume a rise of the production $Y_{L,Urban}$ given that the major sectors in these areas are the secondary and the tertiary sectors, which are growing in developing countries. This leads to an increase in the nominal wages, $W_{L,Urban}$. However, as we supposed that the prices are rising across the whole economy, we have an undetermined effect on the real wage $w_{L,Urban} = \frac{W_{L,Urban}}{P}$: it could either rise, stay constant or fall compared to the level of real wage that the individuals had before the shock. However, it is still higher than the wage they would have received if they stayed in the area of origin. As the production is rising, the labor demand rises also and can absorb the additional labor supply, which maintain the equilibrium on the labor market.

If the area of destination is rural, the conclusion is different. Indeed, the leading sector in those areas is also agriculture in general. It is therefore also affected by climate change. But we assume here that the agents are rational and aware of the climate change. Therefore, we can assume that if they migrate into another rural area, it is because climate change impacts there the agriculture in a lesser extent, or that the individual will not get involved directly in the agricultural sector. Hence, our assumption here is that the production is similar to the one of the previous area before the shock, so $Y_{L,Rural}$ is constant. The nominal wages $W_{L,Rural}$ are therefore also constant for now. As the prices rise, the real wage $w_{L,Rural} = \frac{W_{L,Rural}}{P}$ is decreasing, but lesser than in the area of origin, which allow people to have an incentive to migrate. If we have migration to these areas, the labor supply is growing. As the labor demand remains stable, we expect now a decrease of the nominal wages to preserve the equilibrium on the labor market. We obtain a fall in real wages in both the area of origin and the one of destination if it is rural. This conclusion will have the effect to limit the rural-rural migration. Indeed, people will stop migrating to another rural area is the real wages there are smaller than the ones of their area of origin, given that they have also to take into account the migration costs. However, as long as $w_{L,Rural} \geq w_S + C^i$, people may have an incentive to migrate into a rural area.

Migration into a rural area might be easier for farmers. Indeed, they already have the skills to work there, whereas they might need more time to adapt to the urban areas. We showed in the previous paragraph they can be motivated economically speaking to move to rural areas if the real wages are there sufficiently high. Therefore, it is important to distinguish migration from urbanization, as the former does not necessarily imply the latter.

4 Data

4.1 Indonesia

This section will first present some characteristics on Indonesia.

The Republic of Indonesia is a Southeast Asian country. Being the world's largest island nation, it is also its fourth most populous nation. This emerging middle-income country is also the tenth largest economy in terms of purchasing power parity. During the two last decades, the country has suffered from both the Asian financial crisis in the late 1990's and the 2004 tsunami.

As Indonesia is still a developing country, agriculture remains a main sector of the economy. Its contribution to the country's gross domestic product (GDP) is decreasing for the benefit of the other sectors of the economy (the industry and services). In 2016, according to the World Bank[4], the agriculture's share of the GDP was 14%.

The sector still employs a significant part of the population - 31.8% in 2016 - even if this number is decreasing (54.0% in 1991). Figure 1 in Appendix presents the evolution of the trend between 1991 and 2016. As many of the rural areas depend on the revenues of agriculture, having a stable agricultural production is a critical issue for the populations who live there.

As in most of the emerging countries, Indonesia is characterized by rural depopulation, with strong trends of urbanization. The share of the urban population over the total population keeps increasing, although the trend is less important now than in the 1990s. In 2016, 54.5% of the population was urban, compared to 30.6% in 1990. Figure 2, in appendix, shows the urban population rate's evolution during the last two decades. Therefore, the rural areas concentrate fewer and fewer people. Poverty is here an important issue, with 14.2% of the rural population living under the national poverty line, compared to 11.3% nationally.

We can also note that the emigration trend is rising for this country. We can see with Figure 3 that the net emigration has doubled between 1992 and 2012, with a net outflow of 835,000 people in 2012 compared to 382,000 in 1992. Following the United Nation[5], in 2015, 89% of the emigrants went in a developing region. The International Organization for Migration estimates a net migration flow of -0.5 migrants for 1,000 population over the period 2015 - 2020.

In Indonesia, we can already see some evidence of climate change. Indeed, Case, Ardiansyah and Spector (2007) made a summary of the observed and predicted effects of climate change and its impacts on the society. They note that average annual temperatures have already risen by 0.3 Celsius degrees while the precipitation patterns and seasonality of the precipitations have changed. In Appendix, it is possible to observe this pattern with Figure 4. We can see here that the temperature is rising from 1901 to 2015, with an acceleration starting from the 1980's. As Indonesia is located along the Equator line (and therefore between the tropics), it is expected that the country will experience severe effects of climate change.

[4]World Bank Data, World Development Indicators

[5]United Nations, Department of Economic and Social Affairs, Population Division (2015).

4.2 Indonesian Family Life Survey (IFLS)

The agricultural and migration data come from the household data extracted from the Indonesian Family Life Survey (IFLS).

This dataset was conducted by RAND Corporation. It consists of five waves of surveys (between 1993 and 2015) across 13 of the 27 provinces of Indonesia (figure 5. The sample contains the data of over 30,000 individuals and is representative of around 83% of the Indonesian population. The advantage of the dataset is that the surveyors have followed the respondents over the waves, so we can obtain complete longitudinal data.

From this dataset, I extracted for each wave the data of districts, agricultural business and migration. As the respondents kept a unique ID over the waves, it is, therefore, possible to track them over the years and see whether they are involved in agriculture or not and if they have migrated. The idea is to use the first wave (IFLS1) as a baseline to see whether at least one individual in the household is involved in the agricultural sector. We will also be able to localize them in order to have an initial location and to know in which area (urban or rural) they live. Then we will use the next waves to see whether they changed their location (and if so, was it to go in an urban or rural area) and whether they are still involved in agriculture or not. This will enable us to make an econometric analysis after.

To capture the effect of climate change more precisely, we will only focus on the individuals who have responded to all of the IFLS waves - meaning that they were present and old enough to respond to the first wave and that the surveyors have been able to track them for the other waves. The IFLS data present a variable "mover" at each wave, which indicates whether the individual has moved and, if so, where (different village, district, province,...). Using this variable, I considered that the migration is relevant only if the individual has moved to another Kabupaten (the equivalent of regency). I also checked if they moved to an urban (or rural area). The descriptive statistics will be presented in the section 4.4.

4.3 Weather Data

For the weather data, I used the observations of the NOAA (The U.S.A National Oceanic and Atmospheric Administration), which provides data for temperature and precipitations in Indonesia over a large period of time. I selected the data from 1987 to 2014, in order to cover all years from the first decade before the second ILFS wave (1997) to the last IFLS wave (2014). Over all of the stations observed by the NOAA, 32 are located in the provinces covered by the IFLS. In the appendix, we can see a comparison of the weather stations coverage and the provinces studied by the IFLS (figures 5 and 6).

We will use here annual averages, made with monthly data. To realize the regressions, we will attribute to each individual the weather data associated with his location before each wave. For example, the variables for temperature and precipitation associated to the second IFLS wave are the data of the ten years before the so-called wave, in the location indicated in the first wave. The idea here is to see the effect of changes in the weather that could have motivated the individuals to move.

Figure 4 shows a comparison between the average temperatures observed in the stations and in Indonesia (World Bank Data) during the last two decades. We can see that, even if the temperatures observed in the stations are hotter than the ones in Indonesia in general, they follow approximately the same slowly increasing trend.

4.4 Descriptive Statistics

We present here the statistics for the migration and urbanization variables.

Table 1: Migration by wave and involvement in agriculture

	Any farmer in the HH? (Wave 1)		
When did the ind. moved?	No	Yes	Total
0. Never Moved	5,124	4,327	9,451
	62.16 %	70.25%	65.62%
1. Moved between IFLS 1 and 2	190	52	242
	2.30%	0.84%	1.68%
2. Moved bewteen IFLS 2 and 3	460	200	660
	5.58%	3.25%	4.58%
3. Moved bewteen IFLS 3 and 4	945	542	1,487
	11.46%	8.80%	10.32%
4. Moved bewteen IFLS 4 and 5	1,524	1,038	2,562
	18.49%	16.85%	17.79%
Total	8,243	6,159	14,402
	100.00%	100.00%	100.00%

Table 2: Urbanization by wave and involvement in agriculture

	Any farmer in the HH? (Wave 1)		
When did the ind. go in a city?	No	Yes	Total
0. Stayed rural	6,372 77.30%	4,495 72.98%	10,867 75.45%
1. Moved between IFLS 1 and 2	142 1.72%	26 0.42%	168 1.17%
2. Moved bewteen IFLS 2 and 3	175 2.12%	241 3.91%	416 2.89%
3. Moved bewteen IFLS 3 and 4	825 10.01%	654 10.62%	1,479 10.27%
4. Moved bewteen IFLS 4 and 5	729 8.84%	743 12.06%	1,472 10.22%
Total	8,243 100.00%	6,159 100.00%	14,402 100.00%

With these tables, we can see that the flows of migration and urbanization are increasing with time, even if a large part of the sample did not move. This result is consistent with two facts. First, as we said before, Indonesia is an emergent country and therefore the urbanization process can explain why more and more people are leaving the countryside. But also, a part of the explanation could be the growing pressure from the climate change. The second act is that migration seems to be more important with time. As climate change puts more pressure on the individuals with time, a part of the variation in the migration and urbanization flows might be explained by climate change. However, it is important to study these tables separately. Indeed, as we emphasized before, migration does not necessarily lead to urbanization, as the two processes are separated - although interdependent. Indeed, even if urbanization requires that people migrate, migration can be from one rural area to another, and therefore not impact the urbanization flows. We see here in our sample that there is a larger share of individuals that stayed rural than individuals who migrated. It implies that not every mover went to an urban city. Moreover, our sample includes both rural and urban individuals, which explains why the two first rows are different. Indeed, there are urban people that migrate to urban or rural areas. We shall also remark that it is rather normal that the flows are increasing. Indeed, the first ILFS waves do not capture the precedent moves of the households. Therefore, even if a household has moved before 1993, our data could not capture this displacement. However, as we track the people over 15 years, the displacement patterns are more obvious with time.

We shall note two events may have affected the results. The financial Asian crisis, in 1997 (right after the second IFLS wave) could have refrain individuals from leaving, given the uncertainty created by the event. On the contrary, the 2004 earthquake (and tsunami) that hit Indonesia, and especially one IFLS province, Sumatra, might have created more migration flows between the third and the fourth waves. However, there is no major event that can explain the large rise in migration flows between IFLS 4 and 5.

5 Empirical Model

The objective of the model is to see whether the climate change has an impact on migration, through the change of the agricultural productivity, which is supposed to fall with the rise of temperatures. To capture this effect, we can use both the panel data method and the difference-in-difference method.

As we have data for many individuals over different periods, we can employ the panel data methods. Here, we take as the temporal effect the different IFLS waves and the stations as the individual effect. This enables us to isolate the fixed effects created by the location and time, in order to control for time-invariant district level unobservables. We can do the same exercise for the time, as there may be shocks affecting all locations simultaneously. Therefore, we introduce ϕ_j and ϕ_t, respectively the fixed effects for location and time. We managed to create a strongly balanced panel data by restricting the data set to the individuals present during all of the IFLS waves only.

Secondly, to take into account the agricultural aspect in the regression - in particular, the loss of productivity- we can use the difference-in-difference method and distinguish the individuals with respect to their involvement in the agricultural sector. The idea here is to create a dummy variable, A^i, that would take the valor 1 if at least one person in the individual's household has been involved in the agricultural sector during the first IFLS wave, which is our baseline. The variable takes the value 0 otherwise. The group of individuals who do not work in the agricultural sector is non-farmer group (NF in the following sections), and the group of people who do is the farmer group (F). We expect that the rise of the temperatures should not impact the emigration rates of the non-farmer, whereas it should for the farmer group. In our model, the distinction between the two groups should start after the first wave of IFLS.

The equation to estimate is therefore :

$$\begin{cases} m_{ijtNF} = \phi_{jNF} + \phi_{tNF} + \alpha_{NF} ln(T_{jt}) + \epsilon_{ijtNF} \\ m_{ijtF} = \phi_{jF} + \phi_{tF} + \alpha_{F} ln(T_{jt}) + \epsilon_{ijtF} \end{cases} \tag{9}$$

where :

- m_{ijtNF} and m_{ijtF} are the migration dummies for the non-farmer and the farmer groups respectively,
- ϕ_j and ϕ_t are the fixed effects for location and time,
- T_t is the yearly averages for temperatures,
- ϵ_{ijtNF} and ϵ_{ijtF} are the remaining errors for the non-farmer and the farmer groups.

The same equation will be used for the urbanization, replacing m_{ijt} by u_{ijt}, where u_{ijt} is the dummy variable for urbanization.

Here, I cluster my standard errors at the level of the station.

An alternative approach would be to estimate the effect of agriculture without using two groups. This would allow us to have the same fixed effects for the farmers and the non-farmers. Instead, we introduce the dummy variable A^i presented previously into the regression, which is the involvement of the household in agriculture at the first IFLS wave. It will indicate us whether the farmers are more likely to migrate.

Then, we also use this variable by multiply it by the mean temperature calculated before in order to obtain the variable: $aln(T_{jt}) = A^i \times ln(T_{jt})$. This variable will enable us to capture the effect of agriculture, because here it gives us the temperature only if the individual was a farmer. We will, therefore, estimate the following equation:

$$m_{ijt} = \phi_j + \phi_t + \beta A^i + \alpha ln(T_{jt}) + \gamma aln(T_{jt}) + \epsilon_{ijt} \tag{10}$$

As before, we include the fixed effects for locality and time. Then, the first coefficient, β, tells us if the individual is more likely to migrate given that he was a farmer or not. The coefficient α captures the effect of the migration for all of the individuals while the coefficient γ is only for the people involved in agriculture.

6 Results

6.1 Decade average temperatures

Our objective in this section is to identify the potential effect of rising temperatures on the migration and urbanization in the sample. After removing all of the duplicates and the observations without data for important variables, the sample is composed of 15,040 individuals. However, as the data for temperature and precipitation are scarcer than the ones of migration, the regressions do not necessarily include 60,160 observations (one for each wave for the 15,040 individuals). Also, given the correlation between the temperatures and precipitation data and due to the lack of some observations,we will focus first on the regressions with the temperatures, and then verify our results with the precipitations variables. The following results will, therefore, present only regressions with temperatures variables, unless otherwise stated.

We will estimate the migration and urbanization with different time frames. In order to do that, we first present the regression with the ten-years average lag temperature variable in log to see whether there is an effect of temperature. The results are presented in table 3 below. These regressions estimate the equation (9), with the fixed effects for time and locality, and clustered by station. Column (1) is the regression of migration in the non-farmer group, column (2), in the farmer group, and columns (3) and (4) are for the urbanization, respectively in the non-farmer and farmer group.

Table 3: Effect of temperature in 10-years average on migration and urbanization

	(1)	(2)	(3)	(4)
	moved	moved	urb	urb
Farmer	No	Yes	No	Yes
10-years temperature average	-0.0924	0.905**	-0.128	-0.179
	(0.434)	(0.373)	(0.853)	(0.707)
Observations	29861	22263	29861	22263

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

The first coefficient represents the effect of the mean variation in temperature over a decade on migration for the group of people who were not involved in agriculture during the first IFLS wave. We can see that the coefficient is negative, not statistically significant and close to zero. Hence, we may conclude that variations in temperature do not affect much the migration decision for this population. On the contrary, the coefficient of the second regression for the other group - where people were involved in agriculture during the first wave - is positive and statistically significant at the 5% confidence level. We can interpret this result by saying that variation in temperatures can give an incentive to migrate for the populations depending on agriculture. Indeed, a 1% variation in the decade average temperatures leads to a 0.90 variation in the migration for the farmers in this study. Hence, this result is consistent with the conclusion of the theoretical model presented above, meaning that climate change affects the farmers and give them an incentive to go elsewhere.

The results for urbanization are slightly different. Indeed, we can with the regressions (3) and (4) for urbanization that the coefficients are negative and not statistically significant. This would mean that variation in temperature would, in fact, reduce the incentives for both farmers and non-farmer to migrate from rural to urban areas. We can also observe that the coefficients are close for the two groups, meaning that there is no clear impact of being a farmer or not in the urbanization process.

We can conclude from these first regressions that farmers tend to move more with higher variations in temperatures than non-farmers, but not necessarily to urban areas, unlike what we conjectured before with the micro-level analysis.

We can also run the same regression, but by clustering with households instead of stations. By doing so, we obtain the same coefficients, but with higher significance (at the 1% level) for the estimate of migration for the farmers. Table (8) in Appendix presents the results.

6.2 Decade average temperatures in rural areas

To verify this result, one may want to emphasize the rural areas. Indeed, as we want to see the pattern especially for the farmers, we can select only the people living in rural areas and see whether we obtain the same results or not. As we lose a significant portion of the panel (about 45% of the observations) we will use the following regression as a robustness check. We shall remark also that almost one-third of the non-farmer are not included in the regression (given that they were in an urban area) whereas we lose about 15% of the farmers' observations. We run the same regression as before, but only for the people living in a rural area at the first IFLS wave. Table 4 presents the results.

Table 4: Effect of temperature in 10-years average on migration and urbanization for the rural panel

	(1)	(2)	(3)	(4)
	moved	moved	urb	urb
Farmer	No	Yes	No	Yes
10-years temperature average	0.640	1.042**	3.128*	-0.302
	(0.640)	(0.388)	(1.787)	(0.901)
Observations	10052	18843	10052	18843

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

We see here that the results are quite different for the non-farmers. Indeed, the coefficients for both the migration and urbanization became positive, unlike the results we had before. One explanation is that, given that now we have only rural people who are not depending directly on land as an income source, the incentives to migrate to an urban city are stronger, as the climate change involves rising prices without an increase in the wages. Hence, this population, who may have skills which match better the demand in the urban areas, will tend to move more in order to increase their real wages. The coefficient for urbanization (regression (3)), which is now high and statistically significant, supports this conclusion. On the contrary, the coefficients for the farmers stay quite similar to the previous ones, and the one for migration is now higher and still significant. This confirms the results we had in with the first table (Table 3). These regressions lead to the same conclusions, meaning that, for the farmers, rising temperatures increase indeed the migration, but not necessarily to urban areas.

6.3 Decade average precipitations

We propose now to use other variables to asses the effects of climate change on migration. As the precipitations and temperature variables were too correlated to be included in the same regressions, I used the former as a robustness check. Recent literature showed indeed more ambiguous effects of precipitations on climate change, and our data are less regular for these variables. We will analyze here the effect of precipitations in order to cover the overall impact of climatic variation and compare the results with the ones of temperatures. Table 5 presents the regressions, built as for table 3 but now with the precipitations data. The precipitation variables are built differently. As the climate change affects more the variation in precipitation, the variables are here the ten years averages of the squared difference between the precipitation by year and the overall precipitation average of each station. We estimate here the equation :

$$\begin{cases} m_{ijtNF} = \phi_j + \phi_t + \alpha_{PNF}\bar{P_{jt}} + \epsilon_{ijtNF} \\ m_{ijtF} = \phi_j + \phi_t + \alpha_{PF}\bar{P_{jt}} + \epsilon_{ijtF} \end{cases} \tag{11}$$

with $\bar{P_{jt}} = \left(P_{jt} - \frac{\sum_{t=1}^{T} P_j}{T}\right)^2$ the variation in precipitation.

Table 5: Effect of precipitations in 10-years average on migration and urbanization

	(1)	(2)	(3)	(4)
	moved	moved	urb	urb
Farmer	No	Yes	No	Yes
10-years precipitations average	-0.00194*	0.00143*	0.00202**	-0.000653
	(0.00107)	(0.000765)	(0.000796)	(0.000673)
Observations	21982	17949	21982	17949

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

With these variables, the coefficients are much lower, although the coefficient of migration for the farming group remains positive and significant. The one for the non-farming group is still negative and non-significant, while the coefficients for urbanization are different and from two different signs.

This result confirms the pattern obtained previously, meaning that climate variations have indeed an impact on migration for the farmers, but do not give incentives to this population to go in urban areas.

In Appendix, table 4 presents the results for the decade average for precipitations, but only for the rural sample. We lose here the significance for the coefficient of migration in the farmer group, and the one in the non-farmer group becomes positive.

6.4 Five-year average temperatures

One may want to know after whether this pattern is made in the short or long run. Indeed, it could be interesting to see how fast is the migration decision process and see if it is the years right before the migration that give an incentive to migration or if on the contrary, it is a slow process. To answer this question, we can separate the decade in two and study the effect of the five first years of temperature variation (in average) on one side and the five last on the other. Table 6 present the results of the corresponding regressions. As before, (1) and (2) are the regressions of migration for the non-farmer and farmer groups, and (3) and (4) the ones for urbanization respectively.

Table 6: Effect of temperature in 5-years average on migration and urbanization

	(1)	(2)	(3)	(4)
	moved	moved	urb	urb
Farmer	No	Yes	No	Yes
5-years temperature average (1-5)	0.399	-0.207	0.302	-0.909
	(0.382)	(0.558)	(0.360)	(0.592)
5-years temperature average (6-10)	0.612^{*}	1.029^{**}	0.982^{**}	-0.374
	(0.351)	(0.455)	(0.441)	(0.878)
Observations	20005	16342	20005	16342

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Here, we can see that for the farmer group, the five last years of the decade - the most distant years from the dates of IFLS censuses - are the more important for the migration decision. Indeed, the coefficient for the second half of the decade - the years six to ten - is higher than the one for the first period, and significant. We shall note that the second coefficient is close to the one found in the previous regression for the rural panel (table 4). For the non-farming group, we find the same effect, as the coefficient is high and significant for the second period while it is lower and non-significant for the first period. We may interpret the results from these two first regressions by saying that the migration tends to be a rather slow process and that the long-term variation is more important to the individuals than the short term, especially for the farmers. Indeed, the individuals seem to take more into account the most distant years for the decision process. One explanation could be that the agents tend to prepare their migration and that it is the variation over a long period of time that motivates them to migrate.

Concerning the urbanization, we obtain again negative - and still non-significant - results for the farmer group, suggesting that temperature variation does not influence farmers to go to urban areas. The less negative coefficient is for the last five-years average, meaning that it is rather the long-term variation that could give them an incentive to go to a city. For the non-farmer group, the coefficients became positive and much higher for the second period.

From these regressions, we can learn that the migration decision process tends to be rather slow for the farmers. The results suggest that they take time to respond to climate variation. However, it seems that they are not going to urban areas when they move, which is consistent with our previous conclusions. We see also that the non-farmers tend to go more in cities than the farmers. One interpretation would be that they might have skills more adapted to urban jobs - more related to the secondary or tertiary sector - than the farmers, who might prefer go into other small cities. It could have been interesting to extend this study over a longer period of time (two decades for example). However, due to the limitation of the weather data, which tend to be scarcer by going farther behind, we propose to only study a time frame of one decade.

We propose to check the results with the rural sample. Table 10 in Appendix presents the regressions. As before, the coefficients of migration for the non-farmers group is positive and significant for the second period, as for the farmers' group. They are also higher than the ones in the first period, which confirms the previous results. For the urbanization, we find also a positive and significant coefficient for the non-farmer group and a negative one for the farmer group for the second period. The ones for the first period are both non-significant. These regressions confirm therefore the patterns we have found with table 6.

6.5 Effect of agriculture

We propose now to focus more on the effect of agriculture. To do so, we will join the two groups and estimate the regression (10) proposed in the precedent section. The results - only the estimates for the temperatures - are presented in the following table. Regression (1) is the one of the migration and (2) is the one of urbanization. The first explanatory variable is the 10-year average of the log of temperatures, and the second is the first variable, multiplied by the dummy variable A that takes the value 1 if the individual's household was involved in agriculture at the first IFLS wave and 0 otherwise. Table 7 presents the results.

Table 7: Effect of temperatures in 10-years average on migration and urbanization with the effect of agriculture

	(1) moved	(2) urb
10-years temperature average	0.159	-0.0554
	(0.337)	(0.712)
Farmer*10y temperature average	0.267***	-0.0654
	(0.0474)	(0.0635)
Observations	52124	52124

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

The first coefficient for the migration is attributed to the whole panel - the farmers and the non-farmers. This coefficient is positive, although non statistically significant. It would mean that climate change indeed induces more migration. The second coefficient is the one of interest, which is attributed only to the farmer population. We see here that it is both positive and significant at the 1% confidence level. This allows us to say that there is a statistical difference between non-farmers and farmers and that the latter are indeed more affected by climate change.

Concerning the urbanization, we find low, negative and non-significant coefficients for both of the variables of interest. These results mean that climate change does not seem to have a strong effect on the urbanization flows for both farmers and non-farmers.

This last regression confirms our precedent results, meaning that farmers seem to be indeed affected by migration and have incentives to migrate with higher temperatures. However, they do not tend to go to an urban city, but rather to other rural cities when they migrate. This result is slightly different for non-farmers, as we find non-significant and more variable evidence that people not involved in agriculture are moving with higher temperatures.

7 Conclusion

The aim of this micro-level study was to detect a potential impact of rising temperatures, one of the effects of climate change, on the migration through its indirect effect on agriculture. Our hypothesis was that an increase in the temperatures leads to a fall of the crop yields, which tend to give an incentive to the rural population (and especially the farmers) to leave the countryside and go to an urban area or abroad. With a Roy-Borja model, we found a theoretical threshold (8) which is the lower bound that gives the individual an incentive to migrate. Then, we test the model with a balanced data panel and a difference-in-difference method to see whether being involved in agriculture increases the effect of increasing temperature on migration and urbanization.

What we found is that the individuals involved in agriculture tend indeed to migrate more with higher climate variation than people who are not involved. We showed that this decision tends to be put in place rather slowly, as people take into account around half a decade between seeing an effective climate variation and migrate. However, we did not find evidence that farmers tend to go to an urban area while migrating. It seems indeed that variations in temperatures would, in fact, decrease the incentives to be urban, but this result is not statistically significant. Given these mixed results, we cannot accept our initial hypothesis concerning the urbanization. Farmers are effectively leaving their original location with higher temperatures, but do not necessarily leave the countryside and change their occupation. One explanation we can propose is that they might leave in order to find better job opportunities, but still in the agricultural sector or in a related sector, as they already have the skills for it. They might therefore prefer to stay in rural areas. This result challenges the recent literature on the subject, which found that both migration and urbanization are increasing with higher temperatures.

We observe that, for the non-farmers, we do not find significant evidence of an effect of climate change on migration. This result supports our initial hypothesis, meaning that there is an indirect effect of climate change on migration through its effect on agriculture. We find mixed results concerning the impact on urbanization, which do not allow us to provide a concrete interpretation of the link between climate change and urbanization for people not involved in agriculture.

We shall remember that our results do not take into account many other variables that could negatively impact the crop yield (storms, rising sea levels, impacts of deforestation,..). Other variables not due by human activities, such as the natural soil degradation, put in evidence by Lindert (2000) - may also affect the crop yield. Given the data, we also omitted to include the price stability, which would be hard to capture at a district level. Therefore, this study aims to provide a lower bound of the possible migration response to rising temperatures in Indonesia. Nevertheless, it can provide some useful inputs, with policy implication. Indeed, it is important to take into account the effect of climate change on migration through the impact of agriculture, in addition to the displacements due to natural disasters. As the rise of temperatures is predicted to be stronger in the near-term, the effect put in evidence here will tend to exacerbate and, therefore, lead to more migration flows, added to the actual migration issues. It would be also interesting to focus on the adaptation techniques and see whether they can decelerate this migration process while increasing the agricultural yield.

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9 Appendix

Tables

Table 8: Effect of temperature in 10-years average on migration and urbanization (cluster by Households)

	(1)	(2)	(3)	(4)
	moved	moved	urb	urb
Farmer	No	Yes	No	Yes
10-years temperature average	-0.0924	0.905***	-0.128	-0.179
	(0.245)	(0.281)	(0.169)	(0.269)
Observations	29861	22263	29861	22263

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 9: Effect of precipitations in 10-years average on migration and urbanization for the rural panel

	(1)	(2)	(3)	(4)
	moved	moved	urb	urb
Farmer	No	Yes	No	Yes
10-years precipitations average	0.00256	0.000811	0.00647***	-0.000196
	(0.00169)	(0.000798)	(0.00191)	(0.000745)
Observations	7964	15238	7964	15238

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 10: Effect of temperature in 5-years average on migration and urbanization for the rural panel

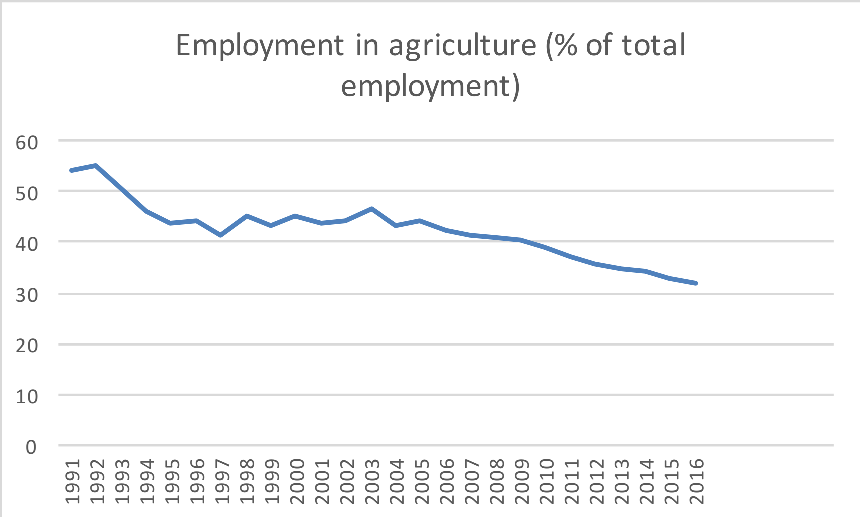
	(1)	(2)	(3)	(4)
	moved	moved	urb	urb
Farmer	No	Yes	No	Yes
5-years temperature average (1-5)	-0.235	0.148	0.273	-1.606*
	(0.325)	(0.579)	(0.751)	(0.856)
5-years temperature average (6-10)	1.156**	0.879**	1.609*	-0.608
	(0.535)	(0.423)	(0.880)	(1.046)
Observations	7322	13884	7322	13884

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

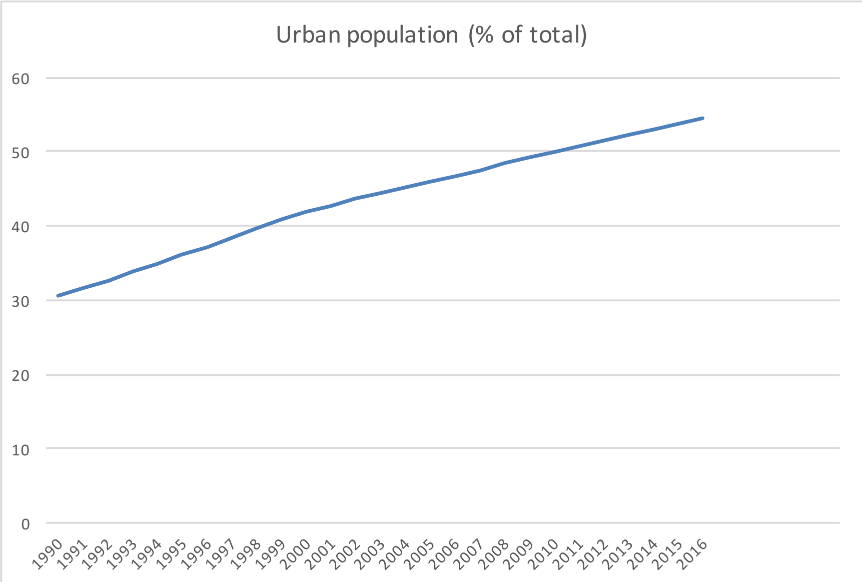
Figures

Figure 1: Employment in agriculture in Indonesia from 1991 to 2016



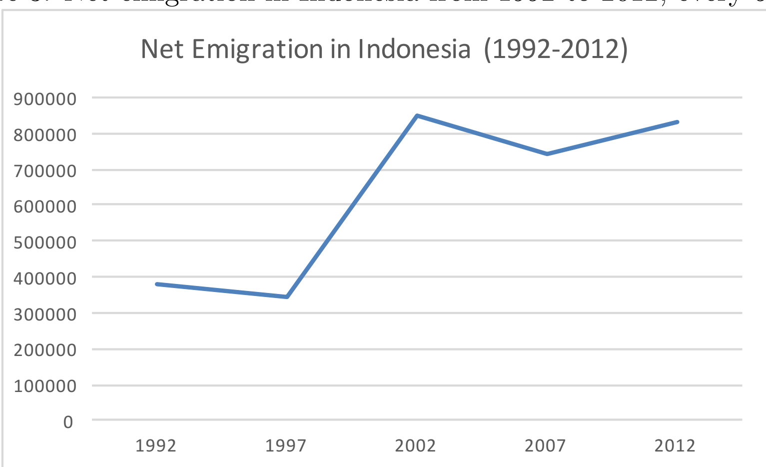
Source : World Bank Data

Figure 2: Evolution of the Urban Population in Indonesia from 1990 to 2016



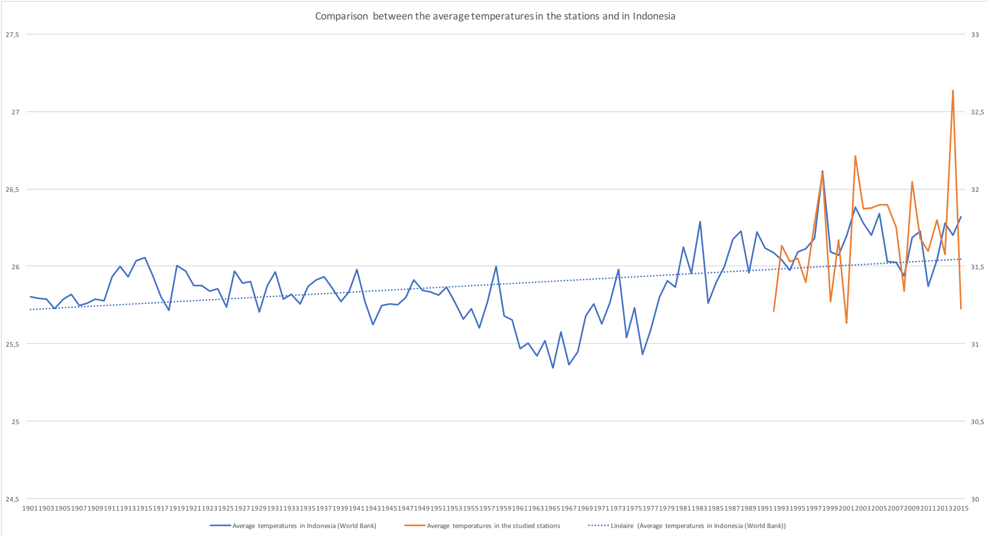
Source : World Bank Data

Figure 3: Net emigration in Indonesia from 1992 to 2012, every 5 years



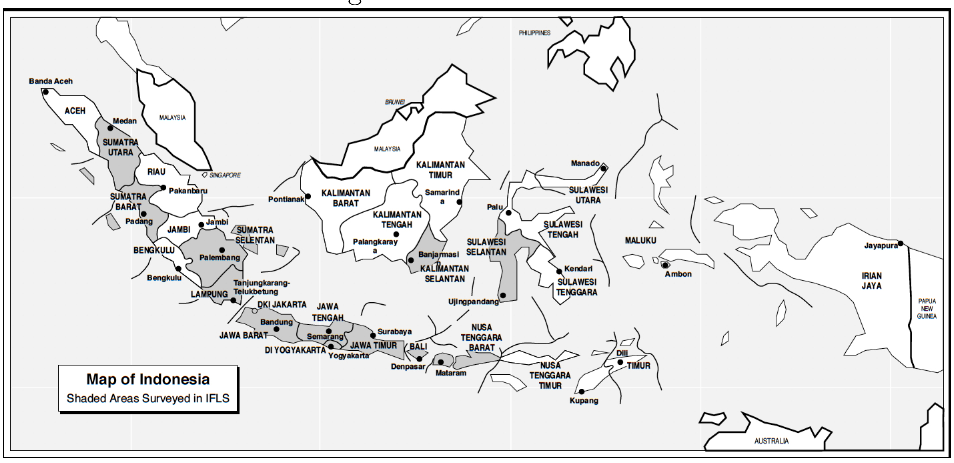
Source : World Bank Data

Figure 4: Comparison between the Indonesian annual temperatures and the ones from the studied Stations



Source : World Bank Data and NOAA (author's calculations)

Figure 5: ILFS Provinces



Source : IFLS Documentation

Figure 6: Weather Stations

Source : Google Maps