William and Mary Center for African Development,

Enclosed you will find first the problem statement and literature review defining the significant problem found in migration as related to climate change, and then the research proposal seeking to identify and explain intransient populations. Migration is a complex issue, and is increasingly becoming influenced by climate change. Populations often use migration as a safety valve to alleviate themselves of climate concerns. This migration in turns has human development impacts, most notably by impacting the migrants ability to be part of the labor force. The unfreedom associated with the inability to be part of the labor force is one of the greatest harms on human development, and results in further violations in human development.

These effects of climate change on migration can be measured with a variety of geospatial data science methods, most notably logistic regression analysis, Baysian belief networks, and gravity models. While the logistic regression analysis was able to test different hypotheses relating to migration by omitting or adding variables, and the Baysian belief network was able to predict scenarios relating to migration and climate change, the gravity model proved to be the most effective. The gravity model effectively analyzed specific areas for covariates relating to the impact of climate change on migration.

It is with a gravity model that this research will use to analyze intransient populations. Intransient populations are those who are unable to migrate to escape climate change related impacts. These populations are more impacted by climate change in terms of human development, as they are unable to use migration as a safety valve. It is proposed that a gravity model will be used to first identify where these intransient populations occur, followed by another gravity model coupled with household surveys to determine why intransient populations occur. Because of the direct impact on intransient populations in terms of human development, this topic is necessary to study. By conducting this research, more specific policy proposals can be made to benefit these populations directly.

Thank you,

Jusitn Maynard

**Problem Statement**

Human migration has been a constant phenomenon throughout history, and is often used as humans adapt and respond to various threats. This process is still occuring today, as humans adapt to the ever growing threat of climate change. These effects of climate change are often felt strongest in areas that rely on agriculture, forcing people to migrate as a form of adaptation to climate change. The effects of migration as a result of climate change can be looked at through the United Nations sustainable development goals, which are various areas of development that seek to be improved upon. This problem relates closely to goals one, three, eight, and thirteen closest. These goals, respectively, are no poverty, good health and well being, decent work and economic growth, and climate action. [11] Migration has the ability to affect poverty, as it could help people escape poverty in situations in which agriculture has become unsustainable, or it could lead to increased poverty as people migrate to slums in large cities. [7] Good health and well being relates to migration, as migration can act as a "safety valve" used to alleviate pressure on resources and unemployment that add to the degradation of well being. [5] Climate action is relevant to this development problem, as taking climate action would reduce the effects of climate change, which would decrease the number of people that must resort to using migration as a form of adaptation to the effects of climate change. Lastly, the most important sustainable development goal relating to climate change and migration is decent work and economic growth. The largest human development impact resulting from migration as a result of climate change is the impact on economic freedoms.

The main issue of human development, as described by Amartya Sen, is the process of expanding the real freedoms that people utilize. These freedoms take five forms: political freedoms, economic freedoms, social freedoms, transparency guarantees, and protective securities. Economic freedom is the principal concern relating to climate change effects on migration as migration is tied to the ability to be part of a labor force. Importantly, there are differing impacts based on whether the migration is voluntary or involuntary. Generally, voluntary migrants are able to preserve their ability to continue to be included in the labor force. Involuntary migrants that are forced to move due to climate issues are more likely to be out of work, a key part of human development.

Nowhere is the convergence of climate impacts and reliance on agriculture more prevalent than Africa. Africa possesses multiple attributes that make it appropriate to evaluate. Firstly, Africa contains large amounts of LMICs, and a large amount of their population depends on agriculture. [1] Specifically in the Sahel, the "marginal agricultural and pastoral" systems that categorize countries like Senegal and Mali, are under severe threat from "desertification, drought, overgrazing, and overpopulation," leading to increased migration. [4] Another reason for the greater effects of climate change on migration in Africa is because of the inability for various African countries to provide solutions. Populations in the Sahel, West, and Equatorial Africa that are more likely to suffer climatic challenges are also more at risk due to "low levels of state and social adaptive capacity." [5] Unfreedoms present with this scenario, such as a lack of social care and absence of government solutions, compounded with the effect of climate change, lead to a decrease in human development as populations are forced to migrate. According to Mastrorillo et al., least developed countries found in Africa lack capital to invest in innovative and technological solutions to climate change mitigation and adaptation, leaving their populations that work the agricultural sector vulnerable to adverse effects in income and employment. [7] This affects the freedom of "protective securities" and "economic facilities" that Sen says are crucial to providing choice and opportunities that contribute to human development. Without proper safety nets in place by governments such as crop insurance, people are forced to resort to migration to solve domestic economic issues. [10] The act of migration itself decreases development, as families are forced to uproot themselves from a community, altering their social opportunities.

Furthermore, research by McLeman and Hunter seeks to quantify the vulnerability and adaptation to climate change, and focus on the West African Sahel region, which was already established as an area with large effects of climate change. According to McLeman and Hunter, the choices made by humans relating to climate change and migrations are "situated within the context of human vulnerability to climate change." [8] Vulnerability is defined as a function of exposure to the impacts of climate change, as well as the ability for communities to adapt, and the sensitivity of communities to climate change, or "the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and

extremes". Voluntary migration is one form of adaptation that households make when threatened with changing environmental conditions in sensitive systems. Consistent with other literature, Mcleman and Hunter state that agricultural and natural resource dependent communities are more sensitive to climate change related effects, increasing the vulnerability of the system.

When looking at harms associated with this human development issue, impacts can be seen at the regional and global scale. Africa, while producing less greenhouse gasses than Eurasia and the Americas, is warming faster than the rest of the world. [1] The climatic effects of this, coupled with the projected increases in population, will lead to increased demand for food, water, and animal feed, putting strain on agricultural systems. If anthropogenic climate change continues, Sahel countries may lose "half of their agricultural output" due to worsening drought, East Africa may face "an expansion of malaria-stricken areas" resulting from increased rainfall and humidity, while West African countries are threatened by rising sea levels. [1] Due to these factors, and the low adaptive capacity of many African countries, the World Bank has projected that there will be 28 million climate migrants from Africa by 2050. [1] The regional impact of this is due to the large number of projected migrants that will put strain on agricultural systems as migrants move towards cities in search of more sustainable jobs, giving up agriculture. [7] Globally, the effect of an increase in climate migrants will be felt on already existing migration patterns in which migrants ultimately seek to get to Europe. Migrants seek to first get to North Africa in hopes of gaining access to Europe, but migration into Europe is often difficult, leaving North African countries strained with an increase in migrants from the south. [5] The increase in climate refugees has effects on global politics regarding migration to Europe, and regional impacts on North African countries as they attempt to handle the strain of large numbers of migrants.

When looking at the phenomenon of migration as related to climate change, the process can be seen as a complex adaptive system. Complex adaptive systems are, as defined by Owen Barder, are circumstances where the economy and society consist of various interactions between evolving adaptive agents that ebb and flow together. Migration in relation to climate change is a prime example of a complex adaptive system, as migration is dependent on the

economy, which is often influenced by climate change, and migration has impacts on society and the economy, showing the interconnectedness of this issue. There are various features of complex adaptive systems, all of which are satisfied by this issue. The most applicable ones are the idea that complex adaptive systems are impossible to predict in detail, yet broad predictions can be made about systems as a whole. In modeling the relationship between climate change and migration, researchers can not predict individual movements due to climate change, but by observing the strength of various variables, broad generalizations can be made about the use of migration as a reaction to climate change. Lastly, the relationship between migration and climate change does not tend towards equilibrium, as migration is constantly being influenced by numerous variables pertaining to climate change. The scale of the problem is also important, as the effects of climate change on migration are studied at individual levels such as different countries or regions within the country.

The scope of this issue ranges from local to regional to the global scale. Locally, migration has effects on the states economy and agricultural output, as migrants tend to move towards cities. Regionally, migration patterns develop where migrants move across states towards places such as North Africa, with the hope of admittance to Europe. While little legal immigration to Europe occurs, illegal immigration often does, which puts strain on European states, showing how the scale of climate related migration has global effects. This migration often occurs because there are little institutions, social services, or infrastructure available to relieve pressures of climate change on agriculturally reliant populations. This leads to migration being used as a "safety valve" to relieve pressure on resources and employment. [5] Due to the lack of state capacity to adapt to a changing climate, migration is used by populations to adapt.

Word Count: 1517

## Literature Review

The geospatial datasets used can be broken up into three methods: classical statistical methods, econometric methods, and machine learning methods. Classical methods combine census or field survey data with remotely sensed climate data using logistic regression analysis, the econometric method analyzed used a gravity model to determine the strongest indicators of migration, and the machine learning method used is a Baysian belief network that represents conditional dependencies between random variables.

### Literature Review - Classical Method - Introduction

In the paper "An Analysis of Large Scale Forced Migration in Africa" by Bayar and Aral, logistic regression analysis was used to investigate causes of large scale forced migration (LSFM). The researchers use ordered logistic regression analysis, as it is more suitable for datasets where the differences among orders are less distinct. This model is applicable to datasets where the dependent variable has a distinct order with at least two or more categories, such as classification of LSFM on a three point scale. The assumptions for the logistical regression model are that "(i) the dependent variable is measured on an ordinal level; (ii) one or more of the independent variables are either continuous, categorical or ordinal; (iii) multicollinearity should not exist among the independent variables." [1] Little multicollinearity is allowed among the independent variables, as multicollinearity is when independent variables are too highly correlated with each other.

### Literature Review - Classical Method - Data

For their study, the unit of analysis is the "country-year", and the countries studies include all continental African countries, within the years 2011-2017. [1] The dependent variable is large-scale forced migration, coded on a three point scale, differentiated between "0—Below 1%," "1—Between 1% and 5%, inclusive" and "2—Greater than 5%" migration percentages. The number of migrants was provided by the UNHCR, the UN's refugee agency. Voluntary migrants were not included, since forced migration is being studied. The independent variable in the study is climate risk. Because Africa is exposed to a variety of climatic zones, the continent is broken up into subregions to capture the diversity in climatic effects. The researchers used Busby et al.'s classification of physical exposure to climate-related hazards.

Busby et at. Mapped physical exposure as an outcome of climatic conditions as well as population density. Based on the study by Busby et al., African countries were put into three categories: “High Climate Risk (i.e., high physical exposure and high/mid-level population density—3), Mid-Level Climate Risk (i.e., low physical exposure and high/mid-level population density—2), and Low Climate Risk (i.e., low physical exposure and low population density—1).” [1] The study also contains five control variables: “violence, political regime, life expectancy at birth (as a proxy for public health), income per capita and official development assistance.” Violence is “an aggregated category” with higher scores representing higher intensity for all “interstate, civil and ethnic conflicts involving a country,” sourced from the Major Episodes of Political Violence, 1946–2017 dataset. [1] The data for the political regime variable was provided row by the Major Episodes of Political Violence 1946-2017 dataset. The political regime data was provided by the Polity IV Annual Time-Series 1800-2017 dataset, in which the Autocracy-Democracy scale ranges from -10 (strongly autocratic) to +10 (strongly democratic). Life expectancy at birth and income per capita were both extracted from the World Bank database. Lastly, official development assistance per capita was tested as a potential remedy for migration. As seen below, Bayar and Aral had six hypotheses related to the study.

H1. The higher the climate risk in a country, the higher the likelihood of large-scale forced migration in this country.

H2. The higher the aggregated level of civil and interstate violence involving a country, the higher the likelihood of LSFM in this country.

H3. The lower the level of democracy in a country, the higher the likelihood of LSFM in this country. (A limitation of this hypothesis is that, in extremely autocratic cases like former East Germany (GDR) or present-day North Korea, large-scale emigration may practically be impossible due to the heavily guarded borders).

H4. The shorter the life expectancy at birth in a country, the higher the likelihood of LSFM in this country.

H5. The lower the income per capita in a country, the higher the likelihood of LSFM in this country.

H6. The higher the official development assistance per capita received by a country, the lower the likelihood of LSFM in this country.

**Literature Review - Classical Method - Findings**

The results from the ordered logistic regression analysis found that civil/interstate violence and political regime type are the most powerful predictors of large scale forced migration, supporting hypothesis 2 and 3. When running the model with all of the control variables, it was found that climate risk was not statistically significant in influencing migration. However, another model was run with the violence variable omitted while keeping the other variables intact. This was done because "if adverse climatic conditions create and/or escalate violent conflicts," running both variables together could make the climate change risk statistically insignificant. [1] When the model was run without the violence variable, climate risk became a strong predictor of large scale forced migration. The overall findings showed that climate change indirectly affected large scale forced migration, most notably by igniting violent conflicts. This contributes to an improved understanding of the human development process as related to migration, as policies that address migration must take climate change mitigation into account in order to decrease effects of violent conflicts.

**Literature Review - Bayesian Belief Network - Introduction**

To explain the process of human migration in relation to climate change, a gravity model and a Bayesian belief network was used. In Drees and Liehr, a Bayesian belief network (BBN) is used to analyse social ecological conditions in the Sahel. [4] A BBN was selected because it is an integrated modelling method, and has a "broad applicability due to its high flexibility in the terms of the underlying data." A BBN is able to portray a large number of different factors and their relations, allowing for the study of causal relationships with climate change and human migration. This particular research developed two models simultaneously to study two areas. Drees and Liehr first mapped migration motives in Linguère, Senegal and Bandiagara, Mali to determine the reasons for migration, and to see if climate change had an impact. They also created a scenario axis to determine if the destination, duration, and motives of migration changed in different scenarios. To cover the environmental influences of migration as well as the societal aspects, they link social-ecological systems (SES) with the concept of ecosystem

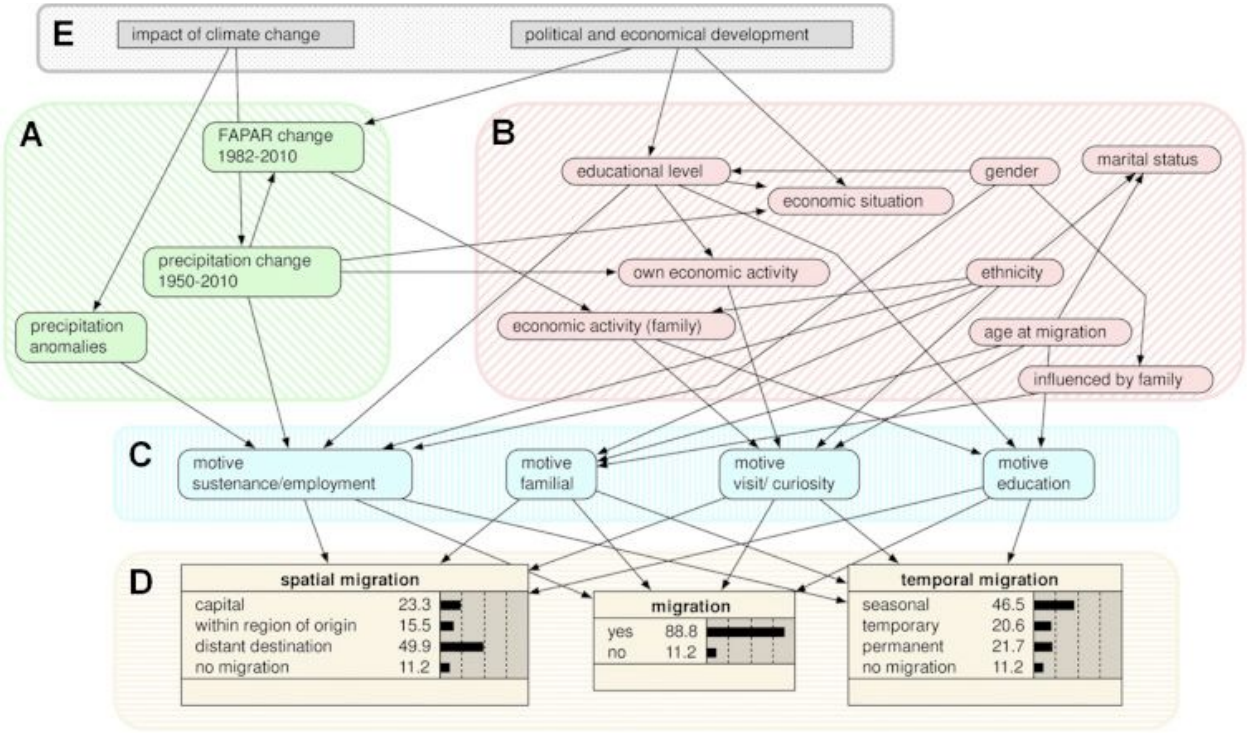
services (ESS). [4] The main component of the migration system is a "natural sphere of the SES" formed by ecosystem functions that "provide ESS to the societal actors." [4] Thus, migration can be seen as a "practice to secure the family's livelihood," which is influenced by SES and ESS systems.

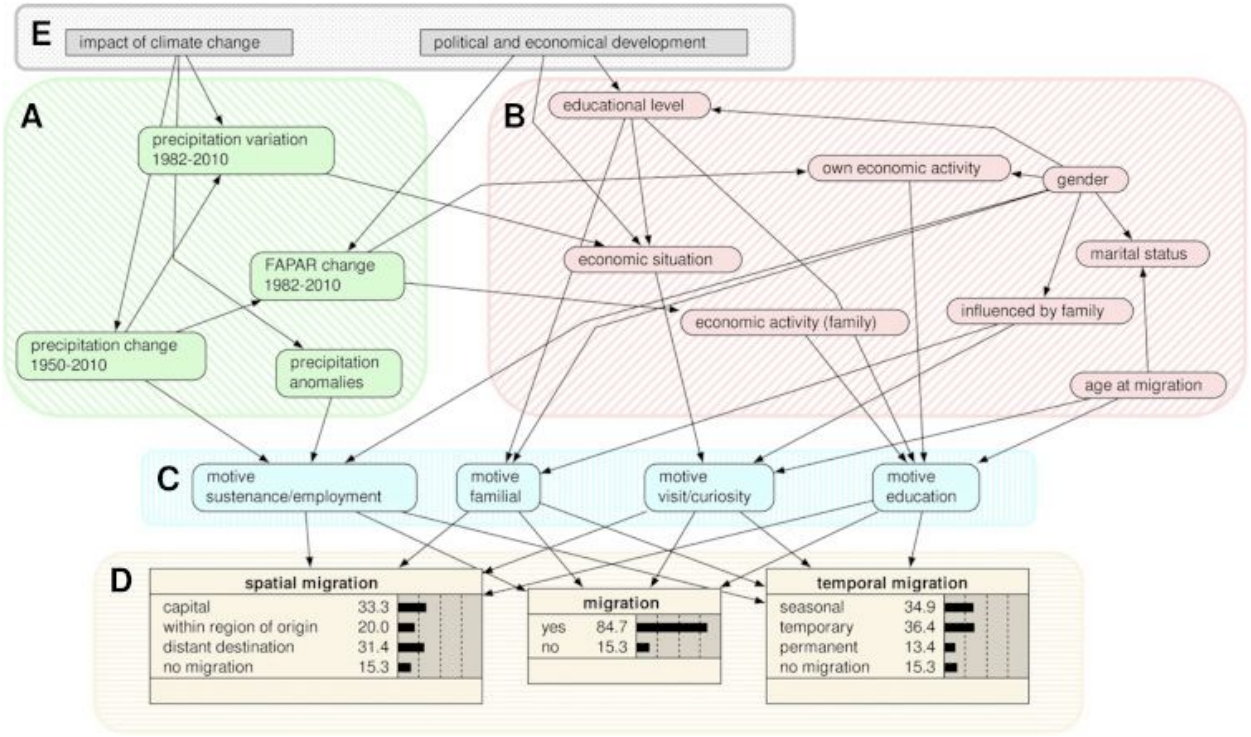
**Literature Review - Bayesian Belief Network - Data**

Drees and Liehr first step in preparing data for the BBN was to classify the variable categories. [4] Social variables classification were determined by the survey, while the environmental variables needed further defining. The socio-empirical survey data covered 905 interviewees, 460 in Senegal, and 445 in Mali. The dataset was then reduced to 337 cases in Linguère, Senegal, and Bandiagara, Mali. [4] The "economic situation" was classified based on data on possession of different goods and access to domestic infrastructure. [4] Environmental variables were classified with the Fraction of Absorbed Photosynthetically Active Radiation (FAPAR) and "precipitation anomalies," values were represented by a deviation of the mean. Migration motives were also based on the survey, and grouped by contextually. The data for environmental conditions was formed by datasets provided by the Research Group of Climatology from the University of Bayreuth. Lastly, environmental data was assigned to individuals survey data to allow for the effects of climate change on migration to be studied.

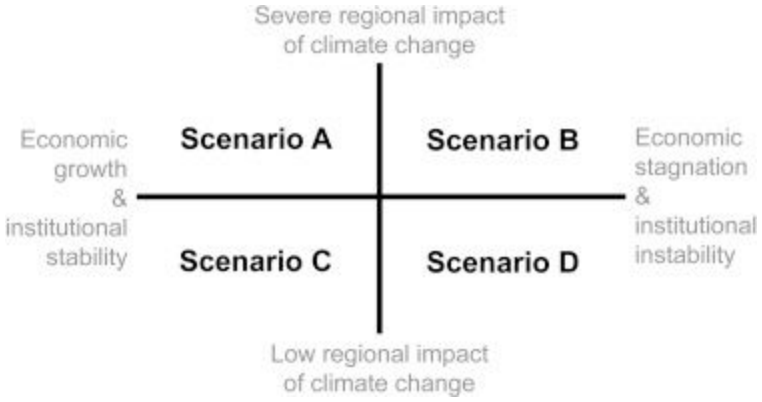
In the BBN structure, "mutually interacting social-ecological conditions" determine the different motives for migration, which "were identified in relation to the characteristics of spatial and temporal migration patterns." This was done by aggregating different answers from survey questions on reasons for migration that relate to comparable motivations. The crucial migration motives identified are "education," "familial," sustenance/employment," and "visit/curiosity." The motives "education," "familial," and "visit/curiosity" are influenced by societal conditions, while "sustenance/employment" is a child node of environmental and social variables. [4] For further development of the model, submodels based on the four models for migration were developed. The submodel for the motives "education," "familial," and "visit/curiosity" included all socio-economic variables, while "sustenance/employment" was split into two submodels, including socio-economic and environmental variables. [4] The model is trained with a randomly selected 85% of the dataset, while the remaining 15% test the models performance in predicting

the migration motive. [4] In the final step, “the interrelations between social and environmental variables are identified according to expert judgements, contextual logic and correlative links.” This allows for the researchers to study the relationships between climate change and migration, and to visualize the most important variables that contribute to migration. Shown below is the BBN trained for Linguère and Bandiagara, respectively.






Another use of the BBN in addition to mapping migration motives was to "estimate altering future developments in different scenarios," with an ultimate goal of policy recommendation. [4] Two axis were used, the first being "politics and economy" describing political stability and economic development. The second axis was "climate," describing low versus severe regional impact of climate change. Four scenarios, "limitation," "crisis," "prosperity," and "stagnation" were analyzed, with regards to consequences in the economy, agriculture, politics, demography, life quality, and the environment. Shown below is the structure of the scenario axis.

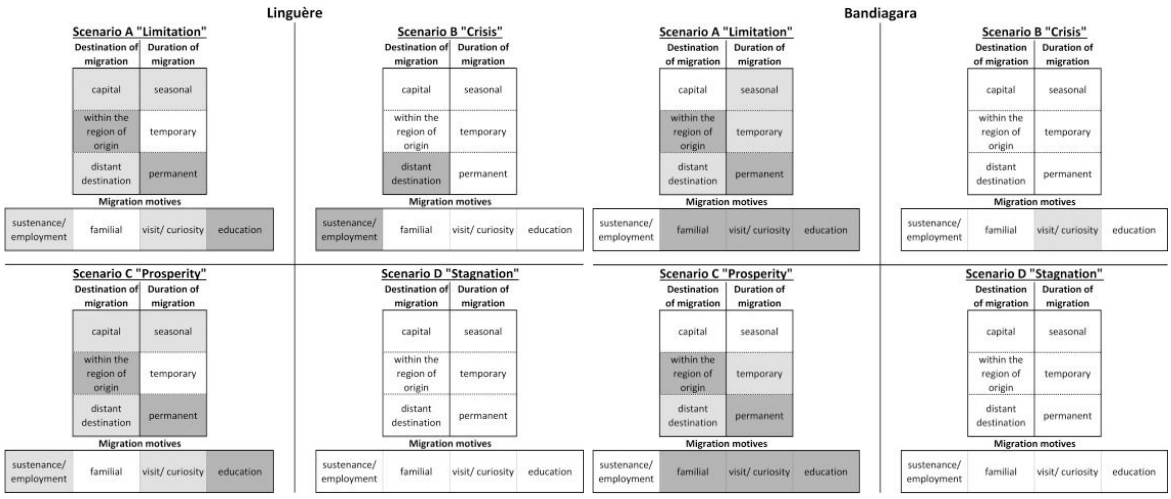



**Literature Review - Bayesian Belief Network - Findings**

When examining the findings of the BBN used by Drees and Liehr to analyze social-ecological conditions for migration in the Sahel, it can be seen that the BBN was successful in plotting scenarios and motives of migration in the Sahel. To determine the reasons for migration in different scenarios, the variables "education," "economy," "precipitation," and "land cover" are changed. [4] This chart below shows the changes in variables during each scenario. These scenarios are then processed by the BBN to determine migration motives in each situation.

| **Variables** | **Limitation** | **Crisis** | **Prosperity** | **Stagnation** |
|---|---|---|---|---|
| **Education** | Positive | Unchanged | Positive | Unchanged |
| **Economy** | Slightly positive | Negative | Positive | Unchanged |
| **Precipitation** | Negative | Negative | Unchanged | Unchanged |
| **Land Cover** | Slightly positive | Negative | Positive | Unchanged |

As shown by the two graphics below, there is a stronger influence from the horizontal "politics and economy" axis than shown on the vertical "climate" axis. [4]




The above graphics show the influence of migration motives, duration, and destinations when presented with different scenarios, and the darker gray colors represent a larger impact. Both studies in Senegal and Mali show evidence of the linkage between "economic conditions

and duration of migration," as non-permanent migrations were common (84.9% in Bandiagara and 76.9% in Linguère), and improved economic situations lead to more permanent migrations. This fact shows the impact of migration on human development. Temporary migrations are undesirable, due to their impact on quality of living, and when economic conditions allow for it, migrants would rather permanently migrate to improve their quality of life. This phenomenon in part can be explained by the desire for education, which is not found in small and remote villages, and a permanent or long term migration is often necessary to complete education. [4] Overall, these findings showed that climate impact, while important, carries less weight than economic and political conditions.

Drees and Liehr observed that the observed low sensitivity to environmental and climatic factors is not explained by their low "de facto significance," or methodological failures. Instead, this is explained by the structure of the BBN itself, which specified environmental nodes as parent nodes to only one migration motive, "sustenance/employment," while socio-economic nodes are parents to all four migration motives. [4] Another issue that arose was that the socio-empirical survey data was often unable to identify interviewees' place of birth, or migrations may have occurred during years not fully covered by data sources. [4] Lastly, the researchers found it difficult to represent the environmental situation for individuals at the correct scale.

**Literature Review - Gravity Model - Introduction**

An alternative to a Baysian belief network, a gravity model, is used by Mastrorillo et al. to evaluate the influence of climate variability on internal migration flows in South Africa.[7] South Africa is a highly relevant case to study, as South Africa has high internal migration rates, consisting of about 5% of the population. [7] Like many other African countries, South Africa is experiencing significant effects from climate change, with an increase of .13 degrees Celsius per decade.[7] South Africa, as a result of aparteid rule, experiences persistent poverty and racial inequality leaving these groups more vulnerable to climate change. Lastly, agriculture is still relevant, as climate variability impact on migration could impact South Africans indirectly or directly "via the agricultural channel."[7] An augment gravity model is used to observe the patterns and determinants of the South African "interdistrict bilateral migration flows" from

1997-2001 and 2007-2011. Determinants such as geographic, socio-economic, and demographic determinants are used, and covariates are introduced to control for the "spatiotemporal distribution of climatic factors."[7] Migration data was collected from South Africa's 1996, 2001, and 2011 censuses, and the 2007 community survey (CS). This census and CS data covers a wide range of information, including demographics, health and fertility, education and employment, morality, housing, households and services, and migration. The 2001 and 2011 census were used to track migration from origin to destination at the district council level. They defined migrants as people who moved between two different district councils within the five years leading up to the 2001 and 2011 census. The five year interval was chosen to the 1996 census and 2007 CS could be used to build a "set of demographic and socio-economic variables" to be used as lagged covariates in their regression exercise. [7] Climatic data was taken from the African Drought and Flood Monitor project, which monitors hydrological conditions of land surfaces in Africa through the Variable Infiltration Capacity (VIC) model. [7] This model provides data on climatic indicators such as precipitation, temperature, and soil moisture, used as a proxy for climate change.

**Literature Review - Gravity Model - Data**

To evaluate the determinants of inter-district migration flows with a gravity model, Mastrorillo et al. first estimates the "Poisson Pseudo Maximum-Likelihood (PPML) with errors clustered at the dyadic level (ij):" [7]

$$m_{\mathrm{ij},t} = \kappa \cdot \exp\{\psi_i + \phi_{j,t} + \boldsymbol{\beta}\mathbf{Z}_{\mathrm{ij}} + \boldsymbol{\theta}\mathbf{X}_{i,\tau(t)} + \boldsymbol{\mu}\mathbf{C}_{i,\omega(t)}\} \cdot \varepsilon_{\mathrm{ij},t}$$

In this framework, i and j are the origin and destination district councils, t is the census years, mij,t represents five year individual migration from i to j. [7] K is a constant, εt/ij is "an error term with mean equal to 1;" ψi are "origin fixed effects;" Φj,t is "time-destination fixed effects;" Zij is a "log of geographic distance between i and j;" Xi,τ(t) is a "vector of lagged demographic and socio-economic" controls at years 1996 and 2007; and Ci,ω(t) is a "vector of origin climatic variables" computed over five year intervals. [7] For the climatic vector, Ci,ω(t), positive anomalies of five year averages of the maximum temperature are used, and to calculate precipitation extremes, positive and negative anomalies of five year averages are used. [7] Also

included in the climatic vector is a measure of soil moisture. The average of relative soil moisture from the five years preceding a census was used. To account for the geography of migration flows as shown in vector Zij , the distance between origin and destination as well as the geographical contiguity between districts is calculated. [7] The last step was controlling for "a number of lagged demographic and socio-economic factors" likely to have an influence on migration flows, represented by $X_{i,\tau(t)}$. The size effects at origin were controlled using total district population to account for highly populated districts possessing larger out migration flows. Another variable was included to account for the differing effects of migration on different ethnicities. Also included in the socio-economic factors was the tendency to migrate towards places offering better labor opportunities, as well as a control for educational attainment.

**Literature Review - Gravity Model - Findings**

The gravity model, as used by Mastrorillo et al. to study internal migration flows in South Africa, showed that geographical, economic, socio-demographic, and environmental factors all played varying degrees of influencing mobility across districts. The gravity models findings revealed that "temperature and precipitation anomalies" from the origin "exert asymmetric push effects" that increase out migration, and rainfall shortages and excess temperature have the strongest impacts. Soil moisture also appears to be another causing factor in out migration. Mastrorillo et al. also found that the relative impact of climate variability has different impacts on different migrant groups, with black and low income South Africans being the most affected. [7] When these groups are more vulnerable, they may be forced to use migration as an adaptation strategy. The researchers identified that this raises the problem of those vulnerable to the impact of climate change, yet "cannot afford migration as an adaptation mechanism." This is a prominent research gap, and threatening to human development standards, as there could be adverse effects like loss in income or employment if people are unable to migrate due to climate change.

**Literature Review - Discussion and Comparison**

When comparing studies completed on migration and relation to climate change, the main difference between a BBN, a gravity model, and logistic regression analysis is that a BBN is able to analyze and predict scenarios relating to migration, while a gravity model is able to

determine factors relating to migration and analyze those factors, and a logistic regression analysis can determine predictors of migration, but does not offer as much in depth modelling. The BBN as used by Drees and Liehr was able to predict scenarios relating to migration and climate change in the Sahel, and individual nodes could be analyzed to determine the reasons for migration. However, the BBN methodology was unable to properly analyze the impact of climate change on migration, as there were more parent nodes leading migration reasons not related to migration. On the other hand, the gravity model as used by Mastrorillo et al. was successful in determining push and pull factors for migration in South Africa. The gravity model was able to break down migration into push and pull factors like race, employment, precipitation anomalies, soil moisture, and temperature anomalies. By taking this data, and using GIS software, the researchers showed how a more detailed look at migration in specific areas can be seen. The logistic regression analysis by Bayar and Aral was able to test six different hypotheses relating to migration by omitting or adding variables. Bayar and Aral found that without their violence variable, climate risk became a strong predictor of migration. However, this model only looked at forced migration, as it was not able to differentiate the causes of migration as specifically as the gravity model. The BBN model is successful in answering the central research question by identifying relationships between climate change and migration through scenario processing, however the gravity model is better fitted. This is because the gravity model has the ability to analyze specific areas for specific covariates, which has more application as relating to improving human development. For example, one could map where push and pull factors such as climatic variables are present, and compare that to a map of actual migration, showing areas that would benefit from migration but are unable to do so. By providing more specialized results, the gravity model is more effective than a BBN or a logistic regression analysis.

One important research gap, that was also briefly recognized by Mastrorillo et al., is that there have been no studies of people who would benefit from migration, but do not have the means to do so. These people, or “intransient populations,” occur when people do not have the resources to use migration as an adaptation to sudden or gradual climatic disasters. Because these people are unable to migrate, they are unable to better themselves in terms of human

development, or their situation could be worsened. The gravity model as used by Mastrorillo et al. would be the most efficient way to determine and then study these populations. Using the output from the gravity model, one could compare actual migration rates to areas with strong push factors, therefore identifying populations that were unable to move. The gravity model also is able to identify specific characteristics of migrants, and that same principle could be applied to intransient populations, allowing for researchers to study why such populations are unable to migrate. The use of a gravity model to study intransient populations could help solve a major research gap.

Word count: 3798

**Research Proposal**

Studying intransient populations is the next logical step when looking at the studies of migration in relation to climate change. To properly determine the existence of intransient populations, and then subsequently the factors leading to intransient populations, a gravity model will be used, focusing on South Africa. Researching intransient populations is highly relevant to the existing body of literature, not only because of the human development impacts, but this study will also advance the studying of migration related issues. Because of the unknown factor of intransient populations, there is a greater opportunity for negative human development impacts. For example, populations unable to migrate due to environmental conditions may be subject to the ever increasingly common occurrence of droughts. [5] Being unable to move, these intransient populations must continue to try to make a living off of agriculture while climate change makes this difficult. Due to the intransients populations inability to adapt through migration, they will incur effects that impact sustainable development goals one, two, three and eight. Goal one, relating to poverty, will have the largest and most obvious impact, as rural populations depend on agriculture, and with a worsening climate will find it more difficult to support themselves. Goal two, relating to hunger, will be a side effect from goal one, as without a sustainable income, hunger is inevitable. These two effects lead to goal three, relating to good health and well being, which will become diminished as the intransient populations fall into poverty as a result of climate change. Because of these pressing effects on human development, intransient populations should be studied. Conducting this study will also advance the literature surrounding migration, as this issue has not yet been developed. By conducting this research, a new field of study in migration is opened up, as it would become possible to study intransient populations caused by a variety of push factors outside of climate change. The importance of studying intransient populations leads to the central research question: What conditions lead to intransient populations affected by climate change in South Africa?

**Research Proposal - Method**

The objective of this research is to first identify intransient populations affected by climate change, and then determine which conditions lead to these populations becoming intransient. To do this, South Africa will be studied. South Africa has been chosen for a variety

of reasons, including a large amount of the population still dependent on agriculture, and already documented impacts of climate change on South Africa. The impact of climate change can be more severe in countries like South Africa that lack sufficient capital to "invest in innovative technologies for climate change mitigation," and without migration as a form of adaptation, intransient populations will suffer more. [7] South Africa has already experienced significant climate impacts with an increase in temperature of .13 degrees celsius per decade between 1960 and 2000, and a trend of a decreasing amount of annual rainfall. [7] South Africa also contains poverty and racial inequalities consequentail of apartheid rule, making some parts of the population more vulnerable to climate change. [7] Lastly, agriculture is still highly relevant in South Africa because of the economic dependence on the commercial sector, and most importantly, the commonality of subsistence farming. [7] It will also be helpful to compare the already existing gravity model used to study migration in South Africa, as the use of similar datasets and research areas will allow for cross examination of the two studies, and better understanding of the effects of climate change on intransient populations.

A gravity model will be used because, as determined by the literature review, the gravity model was the most accurate and reliable in its ability to determine the effects of migration. A similar framework will be applied to study intransient populations. To acquire socio-economic and migration data, census data from 2011 and the 2007 community survey will be used to study intransient populations from 2007-2011. This data will provide information on demographics, health and fertility, education and employment, morality, housing, households and services, and migration. All of these factors will be important in determining intransient populations, and then examining the causes of intransient populations. Climatic data was taken from the African Drought and Flood Monitor project, which monitors hydrological conditions of land surfaces in Africa through the Variable Infiltration Capacity (VIC) model. This model provides data on climatic indicators such as precipitation, temperature, and soil moisture, used as a proxy for climate change.

To first determine intransient populations, a first iteration of a gravity model with the sole purpose of identifying these populations will be run. This gravity model will identify these populations by analyzing areas with strong push factors but smaller than average migration rates.

Variables such as demographic and socio-economic controls will be used in conjunction with a variable representing climatic effects as well as a variable representing hydrological effects such as soil moisture. The demographic and socio-economic variables are likely to have some effect on push factors, and must be controlled for to identify populations affected by climate change. The variables for climatic effects and hydrological effects will determine where push factors are most present. A net migration variable must also be present to determine areas that have lower rates of migration. The results from this iteration of the gravity model will be imposed onto GIS softwares to determine where migration rates are the lowest while push factors are the highest. This completes the first step in the research process, as areas where intransient populations occur will have been identified.

The next step in the research process, determining the causes of intransient populations, contains the most obstacles. In order to get more specific demographic and socio-economic information, localized surveys will be conducted. The conduction of these localized surveys will be costly, and finding the intransient populations may be difficult, as the previous output of the gravity model will not provide data to a high enough resolution. This obstacle will be overcome with the use of remote sensing to find villages where intransient populations live. The advantage over census data is that specific questions related to the inability to migrate will be asked. Once collected, this data from localized surveys will then be categorically organized and sorted, and combined into variables representing reasons for not migrating. These variables will be used in a second iteration of the gravity model, without the original migration variable present, to determine to a higher resolution where intransient populations occur and why they are unable to migrate.

**Research Proposal - Reasoning**

This study should be considered for a variety of reasons, mainly the immediate and pressing human development concern highlighted by the proposal, and the ability for specialized policy suggestions to stem from the research. This study is pressing because of the direct effect on human development, in the form on intransient populations. The presence of intransient populations resulting from climate change is also apparent worldwide, not just in South Africa, and conducting this study will provide a stepping stone to studying this phenomenon worldwide,

therefore discovering the various impacts on human development. Once conducted, this research will also have the ability to offer specialized solutions to this human development problem. First, areas with intransient populations can be identified at a high resolution with help from localized surveys, letting governments know areas that need the most help. Instead of blanket policies, the South African government will be able to offer specialized help to these populations most affected by climate change. Another important aspect in the information obtained from the surveys and used in the gravity model is the ability to determine why populations are unable to migrate. This information could be used to also offer more specific help to intransient populations, whether it be government assistance in migration or economic help. The model being used in this study is another reason in considering this research proposal. The gravity model, unlike forms of linear regression models or Basyian belief networks, is both specific in its findings as shown by Mastrorillo et al., and unlike many Baysian belief networks, is without bias in the model. [4][7]

**Research Proposal - Budget**

When considering the costs, the majority of the costs will occur during phase two of the research, in which localized surveys are conducted in South Africa. It is estimated that travel costs, combined with accommodations and food in South Africa will cost roughly $30,000 dollars. The bulk of this will come from six airplane tickets for myself and five other researchers who will be conducting the surveys. The next largest expense in this category will be accommodations, as temporary accommodations will need to be established as the field surveys will take an estimated one month to conduct. Lastly, an expense will need to be considered to pay for guidance from locals, who will be instrumental in navigation and conducting field surveys. Local South Africans will need to be hired and paid to find intransient populations in remote rural areas, as well as for translation purposes. The census data and climate data from the African Drought and Flood Monitor project will both be available for free, and the creation and implementing of the gravity model will have no substantial cost.

Word Count: 1519

Works Cited

[1] Bayar, M., & Aral, M. M. (2019). An Analysis of Large-Scale Forced Migration in Africa. International Journal of Environmental Research and Public Health, 16(21), 4210. doi: 10.3390/ijerph16214210

[2] Gray, C., & Bilsborrow, R. (2013). Environmental Influences on Human Migration in Rural Ecuador. Demography, 50(4), 1217–1241. doi: 10.1007/s13524-012-0192-y

[3] Gray, C., & Wise, E. (2016). Country-specific effects of climate variability on human migration. Climatic Change, 135(3-4), 555–568. doi: 10.1007/s10584-015-1592-y

[4] Drees, L., & Liehr, S. (2015). Using Bayesian belief networks to analyse social-ecological conditions for migration in the Sahel. Global Environmental Change, 35, 323–339. doi: 10.1016/j.gloenvcha.2015.09.003

[5] Effects of Future Climate Change on Cross-Border Migration in North Africa and India. (2010). Population and Development Review, 36(2), 408–412. doi: 10.1111/j.1728-4457.2010.00338.x

[6] Lu, X., Wrathall, D. J., Sundsøy, P. R., Nadiruzzaman, M., Wetter, E., Iqbal, A., … Bengtsson, L. (2016). Unveiling hidden migration and mobility patterns in climate stressed regions: A longitudinal study of six million anonymous mobile phone users in Bangladesh. Global Environmental Change, 38, 1–7. Doi:10.1016/j.gloenvcha.2016.02.002

[7] Mastrorillo, M. D., Licker, R. D., Bohra-Mishra, P. D., Fagiolo, G. D., Estes, L. D., & Oppenheimer, M. D. (2016). The influence of climate variability on internal migration flows in South Africa. Global Environmental Change, 39, 155–169. doi: 10.1016/j.gloenvcha.2016.04.014

[8] Mcleman, R. A., & Hunter, L. M. (2010). Migration in the context of vulnerability and adaptation to climate change: insights from analogues. Wiley Interdisciplinary Reviews: Climate Change, 1(3), 450–461. doi: 10.1002/wcc.51

[9] Mcleman, R. (2012). Developments in modelling of climate change-related migration. Climatic Change, 117(3), 599–611. doi: 10.1007/s10584-012-0578-2

[10] Nawrotzki, R. J., Riosmena, F., & Hunter, L. M. (2012). Do Rainfall Deficits Predict U.S.-Bound Migration from Rural Mexico? Evidence from the Mexican Census. Population Research and Policy Review, 32(1), 129–158. doi: 10.1007/s11113-012-9251-8

[11] Sustainable Development Goals. (n.d.). Retrieved May 5, 2020, from https://sustainabledevelopment.un.org/?menu=1300