VULNERABILITY OF GLOBAL PRIMARY FOOD PRODUCTION AGAINST EXTREME CLIMATIC EVENTS IN THE CONTEXT OF FOOD GOVERNANCE

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submitted by **Filiz YENİ** in partial fulfillment of the requirements for the degree of **Doctor of Philosophy in Earth System Science Department, Middle East Technical University** by,

Prof. Dr. Gülbin Dural Ünver _______________
Director, **Graduate School of Natural and Applied Sciences**

Prof. Dr. Ayşen Yılmaz _______________
Head of Deparment, **Earth System Science, METU**

Prof. Dr. Hami Alpas _______________
Supervisor**, Dept. of Food Engineering, METU**

Assoc. Prof. Dr. Şule Güneş _______________
Co-Supervisor, **Dept. of International Relations, METU**

Examining Committee Members:

Assoc. Prof. Dr. İsmail Yücel _______________
Dept. of Civil Engineering, METU

Prof. Dr. Hami Alpas _______________
Dept. of Food Engineering, METU

Assist. Prof. Dr. Yeşim Soyer _______________
Dept. of Food Engineering, METU

Prof. Dr. İlkay Dellal _______________
Dept. of Agricultural Economics, Ankara University

Assoc. Prof. Dr. Ergin Murat Altuner _______________
Dept. of Biology, Kastamonu University

Date: _______________

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name, Last name: Filiz YENİ

Signature :

ABSTRACT

VULNERABILITY OF GLOBAL PRIMARY FOOD PRODUCTION AGAINST EXTREME CLIMATIC EVENTS IN THE CONTEXT OF FOOD GOVERNANCE

Yeni, Filiz

Ph.D. Earth System Science Graduate Programme
Co-Supervisor: Assoc. Prof. Dr. Şule Güneş
Supervisor: Prof. Dr. Hami Alpas
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According to latest reports of Intergovernmental Panel on Climate Change, there is a trend demonstrating that the frequency and/or intensity of the extreme climatic events have been increasing, and duration of some extreme events has been changing substantially. Moreover, this trend is likely to continue in the current century, too. The ultimate goal of this study was to identify current vulnerabilities of global primary food production against extreme climatic events in terms of exposure and sensitivity, and to discuss potential entry points for adaptation planning using adaptive capacity (AC) indicators by means of an explorative vulnerability analysis. Outcomes of this analysis are demonstrated as a composite index (CI), where country performances in maintaining safety of food production are compared and ranked against climate change. In order to better interpret the results, cluster analysis technique is used as a tool to group the countries based on their vulnerability index (VI) scores. Results suggest that one sixth of the countries analyzed were subject to high level of exposure (0.45-1)while one third of them were subject to high to very high level of sensitivity (0.41-1 and low to moderate level of adaptive capacity (0-0.59). Results alsa suggested that, in the context of food governance, adaptation options can be supported by establishing independent food safety authorities at national level, and adaptation measures can be included in the private food safety standards at global level. Moreover, in the medium term, blending available public and private standards and promoting its implemetation outside the value chains can be a holistic approach to ensure safety of the global food market. The recommendation of this study is that in order to ensure conceptual coherence of future assessment, the availability of data on food safety related indicators has to be increased.

Keywords: Climate change, vulnerability analysis, principle component analysis, food safety, food governance

ÖZ

GIDA YÖNETİMİ BAĞLAMINDA KÜRESEL BİRİNCİL GIDA ÜRETİMİNİN EKSTREM İKLİM OLAYLARI KARŞISINDAKİ DUYARLILIĞI

Yeni, Filiz

Doktora, Yer Sistem Bilimleri Lisansüstü Programı
Tez Yöneticisi: Prof. Dr. Hami Alpas
Ortak Tez Yöneticisi: Doç. Dr. Şule Güneş
Aralık 2016, 127 sayfa

Hükumetlerarası İklim Değişikliği Panel'inin son raporlarına göre, ekstrem iklim olaylarının sıklığının ve/veya şiddetinin arttığını gösteren bir trend bulunmaktadır ve bazı ekstrem olaylarının süresi önemli ölçüde değişmiştir. Bununla birlikte, bu trendin içinde bulunduğumuz yüzyızda devam etmesi muhtemeldir. Bu çalışmanın nihai amacı, ekstrem iklim olayları karşısında muruziyet ve duyarlılık açısından küresel birincil gıda üretiminin mevcut duyarlılık seviyesini belirlemek ve keşifsel duyarlılık analizi yoluyla uyum kapasitesi indikatörlerini kullanarak uyum planlaması yapmak amacıyla potansiyel giriş noktalarını tartışmaktı. Bu analizin sonuçları, iklim değişikliği karşısında gıda üretiminin güvenilirliğini sağlama konusundaki ülke performanslarının karşılaştırılarak sıralandığı bir bileşik indeks olarak gösterilmektedir. Çalışmanın çıktılarını daha iyi yorumlamak üzere ülkeleri duyarlılık indeksi değerlerine göre gruplamak için kümeleme analizi tekniği kullanılmıştır. Sonuçlar göstermektedir ki, değerlendirilen 118 ülkenin altıda biri yüksek maruziyet seviyeleri (0.45-1) ile karşı karşıya iken, ülkelerin üçte biri yüksek-çok yüksek duyarlılık seviyeleri (0.41-1) ve düşük-orta uyum kapasitesi seviyeleri (0-0.59) ile karşı karşıyadır. Sonuçlar ayrıca göstermektedir ki, gıda yönetimi bağlamında, uyum seçenekleri ülke ölçeğinde bağımsız gıda güvenilirliği otoriteleri kurularak desteklenebilir ve küresel ölçekte uyum önlemleri özel gıda güvenilirliği standartlarına dahil edilebilir. Ayrıca, orta vadede kamu ve özel standartlarının harmanlanması ve uygulamalarının değer zincirlerinin dışında da teşvik edilmesi, küresel gıda pazarının güvenilirliğini sağlamak açısından bütüncül bir yaklaşım olabilir. Bu çalışmanın önerisi şudur ki, gelecekte yapılacak değerlendirmelerin kavramsal uygunluğunu sağlamak için gıda güvenilirliği ile bağlantılı indikatörlerin erişilebilirliğinin arttırılması gerekmektedir.

Anahtar sözcükler: İklim değişikliği, duyarlılık analizi, temel bileşenler analizi, gıda güvenilirliği, gıda yönetimi.

To my beloved family,

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LIST OF ABBREVIATIONS

AC : Adaptive Capacity
BRC : British Retail Consortium
CA : Cluster Analysis
CAC : Codex Alimentarius Commission
CGIAR : Consortium of International Agricultural Research Centers
CI : Composite Index
Codex : Codex Alimentarius
EM-DAT : International Disaster Database - Center for Research on the Epidemiology of Disasters
EU : European Union
FAO : Food and Agriculture Organization of the UN
FAOLEX : Legal Office of Food and Agriculture Organization
FDI : Foreign Direct Investments
FSANZ : Food Standards Australia New Zealand
FSSC : Food Safety System Certification
GDP : Gross Domestic Product
GFSI : Global Food Safety Initiative
GlobalGAP : Global Good Agricultural Practices
GRMS : Global Red Meat Standard
HACCP : Hazard Analysis and Critical Control Points
IFS : International Food Standard
IPCC : Intergovernmental Panel on Climate Change
IPPC : International Plant Protection Convention
KMO : Kaiser-Meyer-Olkin
OECD : The Organisation for Economic Co-operation and Development
OIE : World Organisation for Animal Health
PCA : Principle Component Analysis
PI : Potential Impact

SQF	: Safe Quality Food
UAE	: United Arab Emirates
UK	: United Kingdom
UN	: United Nations
UNEP	: United Nations Environment Programme
UNFCCC	: United Nations Framework Convention on Climate Change
USA	: United States of America
VA	: Vulnerability Analysis
VCI	: Vulnerability Component Index
VCII	: Vulnerability Index Component Indicator
VI	: Vulnerability Index
WB	: World Bank
WMO	: World Meteorological Organization
WTO	: World Trade Organization

CHAPTER 1

INTRODUCTION

Food reaches our table through stages starting from farms, continuing with processing, and ending with distribution and retailing. In all, these sequential stages are called food supply chain. And the very first stage in this chain is called primary food production. Primary food production was defined by European Commission in the General Food Law as:

"The production, rearing or growing of primary products including harvesting, milking and farmed animal production prior to slaughter. It also includes hunting and fishing and the harvesting of wild products" (EC, 2002).

A more detailed definition was made by Food Standards Australia New Zealand (FSANZ), which is a bi-national Government agency, as:

"the growing, cultivation, picking, harvesting, collection or catching of food, and includes the following –

(a) the transportation or delivery of food on, from or between the premises on which it was grown, cultivated, picked, harvested, collected or caught;

(b) the packing, treating (for example, washing) or storing of food on the premises on which it was grown, cultivated, picked, harvested, collected or caught; and
(c) any other food production activity that is regulated by or under an Act prescribed by the regulations for the purposes of this definition." (FSANZ, 2003).

And the following activities were excluded from the definition of primary food production:

"(d) any process involving the substantial transformation of food (for example, manufacturing or canning), regardless of whether the process is carried out on the premises in which the food was grown, cultivated, picked, harvested, collected or caught; or

(e) the sale or service of food directly to the public; or

(f) any other food production activity prescribed by the regulations under the Act for the purposes of this definition." (FSANZ, 2003).

It can be deduced from these definitions that primary food production has two main dimensions: first one is growing or rearing primary food products, and the second one is handling and storing them without causing transformation. From this point of view, primary food production has a direct link to food security in terms of increasing the availability of food to people, and to food safety in terms of being vulnerable to any kind of contamination in the field. Although since 1970s the main focus of international efforts has been tackling food security, which was defined by Food and Agricultural Organization of United Nations (FAO) as "*a condition when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life*" (FAO, 1996), global food problems both with regard to food safety and food security have continued to be unresolved. Despite the fact that these two terms, food security and food safety, are inherently similar, the term food security puts the notion of right to food in the forefront of international attention with the aim of eradicating hunger, while the term food safety has emerged upon the increasing awareness on unintentional spread of food-related illnesses, other than the ones arising from pesticides and mycotoxins, by addressing mainly public health. At this point it becomes more obvious that food security is an on-going issue for the Southern countries, while food safety is a priority for the Northern countries to meet the disease-free food demand of public. Therefore, integrated but differentiated governance strategies have to be implemented for these top two food-related global problems.

In today's globalized world, either raw materials or final food products are produced around the globe in climatically, culturally and legally diverse places on their way to our kitchen counter. The cultural differences may lead to changes in diet preferences, and the legal differences, together with in-place institutional mechanisms, may lead to important changes in food governance strategies. Likewise, changing climatic patterns appear to be a fundamental contributor to the food- related incidents as much as the cultural, legal and economic environments in the countries of origin and destination. Impacts of climate change and climatic oscillations (such as el Niño Southern Oscillation and Indian Ocean Dipole) on food security are well documented by focusing on changing crop yields, crop (especially grains) and livestock loss on spatial scales ranging from a state and nation (Ghahramani & Moore, 2016; Hague, Braganza, & Jones, 2016; C. Li, Wang, Ning, & Luo, 2016; Liu, Liu, Yang, Bai, & Wang, 2015; Spencer & Polachek, 2015; Swaminathan & Rengalakshmi, 2016; P. Wang et al., 2016) to region and the globe (FAO, 2016c; Lassa, Lai, & Goh, 2016; Özkan et al., 2016). The aim of increasing food security efforts appear to be increasing access to food, eradicating hunger by increasing yields and focusing on animal and plant health, supporting people to have more balanced diets. The other side of the coin, is the food safety, has emerged upon increasing awareness on unintentional spread of food-related illnesses by addressing mainly public health and human welfare. However, it barely attracts scientific attention when it comes to global scale assessments.

Aside from food terrorism, which is defined as "*an act or threat of deliberate contamination of food for human consumption with chemical, biological or radionuclear agents for the purpose of causing injury or death to civilian* *populations and/or disrupting social, economic or political stability*" (WHO, 2002), climate change has emerged as a major pressure on microbial and chemical safety of food as a natural threat whose consequences can not be obviated. Major consequences of climate change affecting food safety have been reported as changes in temperature and precipitation patterns, ocean warming and acidification, and increased frequency and intensity of extreme climatic events (Kirezieva, Jacxsens, Van Boekel, & Luning, 2015). Since using proxy indicators for ocean warming and acidification to compare country performances is futile on a global scale and effects of changes in temperature and precipitation patterns on food safety shows significant regional differences (Kim, Park, Chun, Choi, & Bahk, 2015; Tirado, Clarke, Jaykus, McQuatters-Gollop, & Franke, 2010), frequencies of extreme climatic events appear as appropriate target as exposure indicators to assess country performances on a global scale.

Primary food production is particularly vulnerable against such large-scale changes in patterns of extreme climatic events because the very beginning of food supply chain starts at farms by directly being exposed to climatic events (Marvin et al., 2013). The fact that food safety incidents often originate in the early stages of food supply chain not only holds true for crop production, but also for dairy and meat production (Jooste, 2008; Norrung & Buncic, 2008; Yeni, Yavas, Alpas, & Soyer, 2016). Moreover, if contamination occurs in the primary production phase, the risk of cross contamination due to distribution of the food products will be much higher than expected (Gorny, 2006; Sofos, 2005). Therefore, the objectives of the present study were to conduct an explorative vulnerability assessment on a global scale, focusing primarily on food production stage in order to reveal current vulnerabilities and to discuss adaptation options to propose a holistic solution. To this end, it was aimed to define which extreme climatic events put pressure on food safety, which characteristics make countries more prone to exposure, and which tools can be used to facilitate climate adaptation in order to determine the levels of exposure, sensitivity and adaptive capacity (AC), respectively. Afterwards, a cluster analysis (CA) was conducted with the aim of evaluating policy implications in terms of the

Northern and Southern countries. And finally, a nonparametric correlation was carried out in order to reveal weather there is a link between availability of a national food safety authority and the vulnerability index results.

1.1. Trends in Extreme Climatic Events

Intergovernmental Panel on Climate Change (IPCC) is an international body which was established by the World Meteorological Organization (WMO) and United Nations Environment Programme (UNEP) in order to provide a scientific basis to policymakers of national governments, and to underlie negotiations at the United Nations Framework Convention on Climate Change (UNFCCC) (UN, 1988). In this resolution adopted by UN General Assembly in 1988, climate change was prioritized as a global problem and declared as a common concern of mankind (UN, 1988).

Since its establishment in 1988, five assessment reports were published on the state of climate change together with associated future risks, and adaptation and mitigation options with voluntary contribution of hundreds of researchers from the member countries of the WMO and UN. As the first assessment report was published in 1990 and provided the scientific basis for the UNFCCC negotiations in terms of bringing human-induced climate change to the forefront of global attention, the sequent reports also directed the theme of negotiations towards adaptation and preventing catastrophic levels of climate change at the Conference of the Parties (COP), which is the supreme decision-making body of the UNFCCC (Roberts & Huq, 2015). Although IPCC bases its reports on available literature instead of conducting research (IPCC, 2013b), these reports are among the most cited publications in the climate-related research papers because of the organizations historical backround and the collective effort made in preparation of the reports.

As reported by the fifth and the latest assessment report of IPCC, occurrence of the heat waves over most land areas has increased since the middle of the twentieth century and it is likely that the frequency and the duration will increase in the current century (IPCC, 2013a). It was reported with high confidence that as the global mean surface temperatures rise, extreme precipitation events will continue to increase in frequency and intensity faster than the time's average, and remarkably, the contrast of annual mean precipitation between dry and wet regions, and between wet and dry seasons would increase over most of the globe (IPCC, 2013a). Likewise, it was classified as to be likely that intensity and/or duration of drought and flood events will increase due to decreases in soil moisture (IPCC, 2013a). It was also reported that there is a shift to more intense individual storms and fewer weak storms in terms of short-duration precipitation events(IPCC, 2013a). And mean tropical cyclone maximum wind speed and rain rates have increased despite the global frequencies were likely to decrease or remain unchanged (IPCC, 2013a). Apart from IPCC, several regional meteorological monitoring institutions reported on the current situation of the extreme climatic events. For example, European Drought Observatory annually reported increased number of occurrence of extreme temperature events (hot and cold), increased duration of droughts, and severe soil moisture deficits over large areas (EDO, 2015). Likewise, 2000-2016 period was the largest and most persistent drought for the West of the United States of America in the historical record (NOAA, 2017a). Moreover, U.S. Climate Extremes Index (USCEI) for 2016 was 95 % above average, the third highest value on record (behind 1998 and 2012) and mostly min. and max. temperature values contributed to this index values (NOAA, 2017b).

1.2. Structure of Global Food Governance

Governance is defined as an exercise of authority or management of resources through institutions, policies, traditions, cultures and societal norms (Pinstrup-Andersen & Watson, 2011). Therefore, in the context of food governance, ensuring food safety throughout the food supply chain, namely in production, distribution and consumption stages, requires a systems approach. This approach shall not only encompass the main stakeholders, which are producers, processors, retailers, policy-makers and consumers, and the relationships involved between these stakeholders but also include the functional institutional mechanisms focusing on environmental and economic aspects of global food system (Pinstrup-Andersen & Watson, 2011).

Despite the presence of several United Nations (UN) institutions (such as FAO and World Health Organization (WHO)), the Bretton Woods Institutions and the World Trade Organization (WTO), there is no central authority governing all aspects of food (Busch, 2011). With respect to agriculture, food and nutrition, international institutions and national state governments have underinvested in public goods such as agricultural research and rural infrastructure and institutions, which have considerable global impact (von Braun, 2008). In the absence of such a comprehensive global food governance structure, there are a myriad of measures addressing different aspects of food safety in a variety of levels. In this sense, standards are a crucial part of global food governance because their implementation shapes how food is produced, processed and distributed (Fulponi, 2006).On one hand, global food policy and public standards are shaped through collaboration of sovereign states in the realm of international politics, but on the other hand there is a market-driven governance approach through soft law, e.g. the private standard setting.

Figure 1 summarizes the fragmented structure of global food governance in terms of global standards. For the rest of this section, historical backround and current situation of this fragmentation were explained in detail.

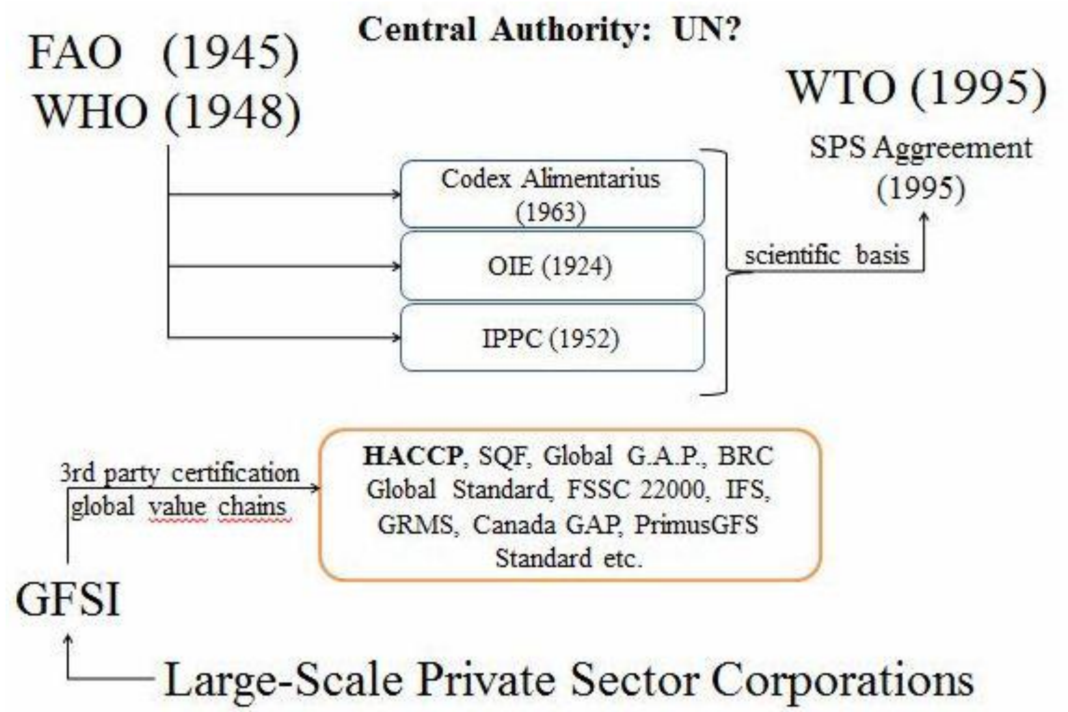

Figure 1 Fragmented Structure of Global Food Governance

1.2.1. Public Standards

Governments generally set minimum standards for products and processes in relation to consumption externalities, such as food safety (Fulponi, 2006). Likewise, as the main source of the international public law on food safety, there are multilateral agreements on production, environmental challanges (climate change, biodiversity and other natural resources) and trade aspects of food supply, however, the resulting legal instruments may lack enforcement mechanisms or may contain ambiguities because of power imbalance between negotiating sovereign states (Barling & Duncan, 2015; Coleman, Grant, & Josling, 2004). Since its establishment, FAO aimed to combat hunger and prevent food crises throughout the World by reaching beyond the scope of the measures taken by the governments of the national states, however, assigned the responsibility solely to the national states and in the legal texts avoided taking critical actions against multinational corporations and the Bretton

Woods institutons, both of which develop mechanisms affecting global food governance (Gonzalez, 2010).

As the main source of global standards on food safety, Codex Alimentarius Commission (CAC) was established by FAO and WHO in 1963 in order to be the leading global organization in ensuring safety and quality of food products via nonbinding standards, guidelines, and codes of practice. The former offered insight into agricultural and nutritonal aspects together with access to food as a human right, and the latter contributed exprience to public health aspect of the issue. Moreover, FAO and WHO create capacity building programs on food safety and quality based on the scientific basis and standards that Codex provides (Glasner, 2015). Similar to the role of CAC in food safety, World Organization for Animal Health (OIE) and International Plant Protection Convention (IPPC) had promulgated nonbinding standards, guidelines and codes to reflect the international consensus with respect to animal health (including zoonoses) and plant health, respectively, however, their legal status were elevated in 1994 and since then international food trade rely upon these three public standards because WTO refers to these public standards in the Agreement on the Applicaton of Sanitary and Phytosanitary Measures (SPS) in order to provide scientifically sound risk assessment in order to discourage importing countries to impose unattainable measures for trade (Brückner, 2009). This way CAC, OIE and the secretariat of IPPC, which is hosted by FAO, became global regulatory authorities but the decision-making practices, especially in CAC, changed after this milestone since its outcomes became binding in such a way that WTO member states have the right to sue other members for applying environmental and food safety standards that are stricter than the Codex standards under SPS Agreement (Winickoff & Bushey, 2010). In this framework, the role of OIE, which was founded in 1924, is designing methods to control international spread of aquatic and terrestrial animal and human pathogens (zoonoses) and managing food safety risks arising on-farm from animals, diseases at the human/animal interface (Kahn & Pelgrim, 2010). On the other hand, the role of IPPC, which was entered into force in 1952 and whose secretariat is hosted by FAO, is setting standards in order to prevent and control international spread of plant pests (any organisms that are harmful to other plants) and diseases without exercising undue influence over international trade (MacLeod, Pautasso, Jeger, & Haines-Young, 2010). As mentioned above, main public law instruments regarding food, plant and animal safety have an aim of facilitating international trade, however, trade policies and standards has impeded the capacity of some countries in the Southern countries to develop their own agricultural system (von Braun, 2008).

1.2.2. Private Standards

Due to declining tariffs and quotas as a result of negotiations under the leadership of WTO, declining costs, and the use of information technologies to manage longer supply chains with higher speed, food processors could reach a variety of cheap and abundant raw food stuff and food market has globalized in the last decades (Busch, 2011). Globalization of food commodity trading and foreign direct investments (FDI) has lead to increased market concentration at all levels of supply chain and the rise of supermarkets in the whole globe, which in turn strengthened the hand of processors and the retailers to shape the production decisions especially in developing countries (Barling & Duncan, 2015). This shift in market structure from agricultural commodity markets to product markets with large-scale processors, wholesalers and retailers urged these stakeholders to set private standards on food quality and safety in order to protect themselves from the risks associated with the instabilities and risks in the previously inacessible, newly opened markets by tying producers to particular buyers (Busch, 2011). However, these newly imposed standard schemes increased concentration of food markets even more since the countries with adequate institutional capacities or mostly large firms having high operational capacities were able to compansate the cost of compliance and benefited high regulatory standards but small producers left outside the competition (Chatzopoulou, 2015; Pinstrup-Andersen & Watson, 2011). In order to engage the small producers in the developing World to the food markets in the Northern countries through global supply chains which requires compliance to private standards, the term global value chains were introduced as a new governance strategy (Gereffi et al. 2005). Although these private standards are technically voluntary, their compliance requires contractual agreement and their role in global governance of argo-food value chains is particularly relevant for developing countries which can be excluded form the global market if do not engage in this new governance scheme (Fulponi, 2006). International agencies such as the ones in the Consortium of International Agricultural Research Centers (CGIAR) have been setting a up clearinghouse to engage the small producers in the agro-food value chains (Barling & Duncan, 2015).

Starting from the 1980s, private investment prevailed over public investment in agricultural research in order to achive the goal of increasing quality and a new set of standards emerged (Busch, 2011). Contrary to the previous understanding of standards to incerease productivity, market-driven food governance approach through soft law is mostly composed of voluntary private standards, not only in the realm of food safety, but also in the area of fair trade, animal welfare, environment and sustainable production in order to increase accountability, meet societal expectation and stay in the competition (Barling & Duncan, 2015; Busch, 2011; Fulponi, 2006). To meet the requirements of the private standards, food industry also introduced food product certification schemes and traceability systems along with voluntary private certifying initiatives such as the Global Food Safety Initiative (GFSI) which was founded in 2000 in order to bring together the stakeholders and approve a food safety management system, starting form the farm level to packaging, storage and distibution, if it meets the requirements (Busch, 2011; Chatzopoulou, 2015). Safe Quality Food (SQF), Global Good Agricultural Practice (Global G.A. P.), British Retail Consortium (BRC) Global Standard, Food Safety System Certification (FSSC) 22000, International Food Standard (IFS), Global Red Meat Standard (GRMS), Canada GAP, PrimusGFS Standard, can be listed among the approved food safety management systems.

There are certain examples that the private standards and third party certification schemes become institutionalised by nation-states and even converted into public standards or lead to public private co-regulation, such as Hazard Analysis and Critical Control Point (HACCP) (Busch, 2011; Chatzopoulou, 2015). HACCP is recommended by Codex, recognized by many governments and eventually became the prevailing voluntary food safety standard in the processing stage in Europe, North America and the countires exporting their products to these markets since 1990s offering a preventive approach as opposed to end-product inspections (Fulponi, 2006; Wengle, 2016).

Although private standards seem like a complementary instrument, their capacity to ensure food safety extends beyond the public law. In fact, the private sector and international organizations are taking the lead in shaping global food and quality standards (Fulponi, 2006). However, only the countries with adequate intitutional capacities or mostly large firms having high operational capacities are able to compansate the cost of compliance and benefited high regulatory standards (Busch, 2011). Since implementation of the private standard schemes is not mandatory, they are not implemented outside the global value chains, especially in the national food markets of the Southern countries because of economical and political priorities. Also, it is not clear who would be accountable when there emerges a food safety-related issue in the food chain in such a unharmonised, fragmented global governance structure (Chatzopoulou, 2015). Therefore, the current situation is both unstable and likely to change in the near future since environmental and food security-related problems have continued to be unabated (Busch, 2011). But there is not much room for scaling the existing international structures up and coordinating them efficiently under existing conditions (von Braun, 2008).

This study was organized in five chapters. In the Chapter 2, the methodology and the conceptual framework on which the study was based was presented in detail. In the scope of this framework, the reasons behind the assumptions and decisions made in the analysis were explained and steps of the analysis were revealed. Also, cause-effect relationships were set between food safety incidents and extreme climatic events through impact chains in this chapter. In Chapter 3, results of the PCA and

CA were presented and evaluated in terms of the Northern and the Southern countries. In Chapter 4, results of these analysis were discussed and compared with the studies in the literature, and policy recommendations were made for decion-makers both at national and global scale. In Chapter 5, concluding remarks were made. And, finally data tables and additional results of PCA were presented in the Appendices chapter.

CHAPTER 2

MATERIALS AND METHODS

2.1. Conceptual Framework

Until the fifth assessment report, vulnerability was defined by IPCC as a systematic approach comprising of three elements (exposure, sensitivity and AC) which, as a whole, was used as a tool to analyze the propensity of the overall system to be adversely effected by a factor (IPCC, 2007). Although the last report focuses on the notion of social vulnerability by phasing out the exposure component, the classical notion of vulnerability is still considered as a highly effective way of identifying and prioritising adaptation interventions (Fritzsche, 2014). To this end, both biophysical (exposure) and socio-economic (sensitivity and AC) dimensions were integrated into vulnerability analysis (VA) in order to provide a underpinning for discussion. In this study, principle component analysis (PCA) was used to construct the composite VI because composite indices (CI) are recognized as useful tools in identifying trends and providing simple comparison of countries in highly complex issues (Munda & Nardo, 2009; OECD, 2008). However, in literature, there is an ongoing debate on each step of constructing CIs and on taking the outputs of CIs as the sole base for policy making. In a recent study (Santeramo, 2015a), by comparing different food security CIs based on the same data, it was concluded that choosing relevant data and the right methods for data imputation and aggregation are crucial while the choice of normalization and weighting methods are less of a concern. Reaching the relevant data to construct the index is the first issue which has to be addressed by the researchers. For instance, for food safety related indices with global coverage, lack of the data on foodborne outbreaks, prevalence of in-place food safety management schemes, or choice of traceability systems, level of adaptation efforts made by each country creates the main shortcoming of an index. After the data collection stage, imputating the mising data is a critical step because imputation may lead to biased estimates depending on the method used and the percentage of missing values in the dataset (OECD, 2008). For normalisation, there are various methods and each of them having its limitation. But the most widely used ones are standardisation and min-max normalisation, both of which are effected by the outliers in the data (OECD, 2008). For weighting indicators, there are a whole range of statistical and participatory methods. Researchers may choose factor analysis or PCA if variables are correlated, or equal weighting method can be chosen if there is a prior information that the indicators have equal contributions to the index (Santeramo, 2015b). For the last stage, aggregation, linear or nonlinar aggregation methods can be used by the researcher depending on the compansability of the components of an index (Munda & Nardo, 2009). In total, considering the complexity of the realm of climate vulnerability and safety of food production, and the limited nature of available indicators in terms of relevance, discussions on outputs of composite indices need to be considered as hypotheses rather than definitive conclusions (Barré, 2001; Hoskins, Saisana, & Villalba, 2015). In this sense, a statistically sound and conceptually coherent index was aimed to be built by ensuring the transparency of method selection. Steps of the vulnerability analysis (VA) are shown below (Figure 1):

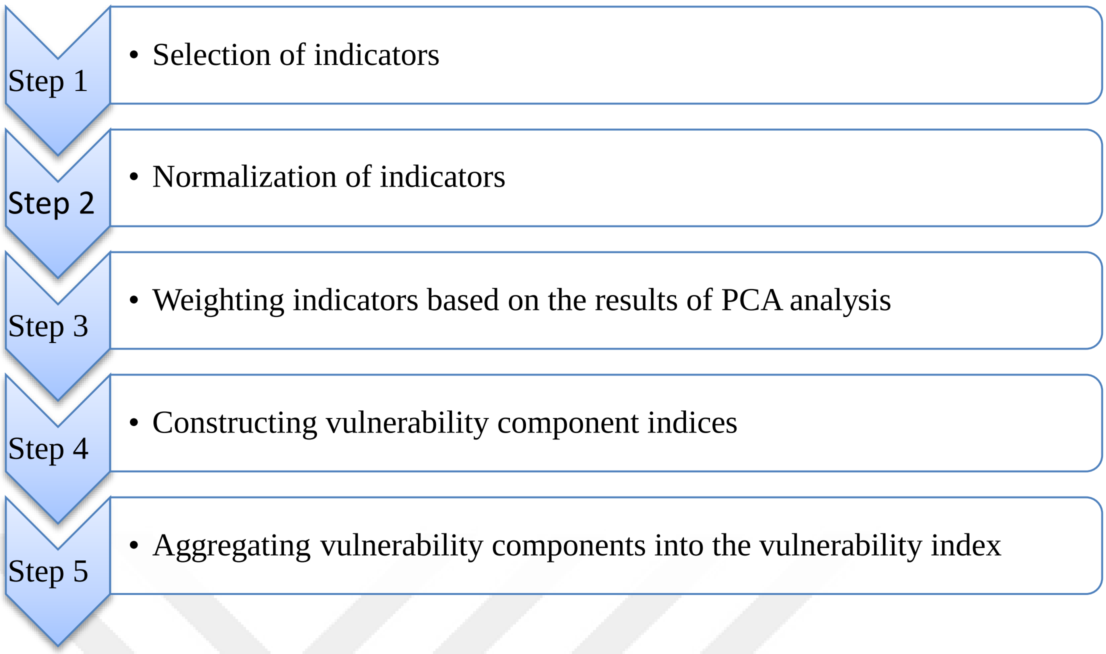

Figure 2 Steps of Vulnerability Analysis

In designing the study, a theoretical framework was established not only for ensuring the assumptions made to select relevant indicators and the methods are transparent and stable, but also for providing repeatable and comparable results (Nelson, Kokic, Crimp, Meinke, & Howden, 2010). In order to improve overall quality and robustness of the composite index;

(1)Extreme climatic events were associated with microbial or chemical contamination of food (crops, feed and livestock) and production environment through impact chains (Fritzsche, 2014).

(2) The most relevant and available indicators with global coverage, and up to date records were chosen and collected from open-access sources for the index to be repeatable and transparent (FAO, 2016a, 2016b; Guha-Sapir, 2016; WB, 2016). Analysis were performed with no missing data. Instead of making missing data imputation, the countries lacking data were excluded from the analysis, and, for this reason, number of countries were downsized from 193 to 118.

(3) The direction of indicators was adjusted where necessary, in order to demonstrate the trend, where lower values reflect decrease in vulnerability.

(4) Weights assigned to each indicator of each vulnerability component after running a PCA proposed by Gomez-Limon & Riesgo in order to avoid subjective results (Gomez-Limon & Riesgo, 2009).

(5) Monte Carlo simulation was performed after PCA in order to determine the number of principal components to be extracted from the analysis (O'Connor, 2000).

(6) Normalized exposure and sensitivity scores were linearly aggregated into potential impact, and afterwards normalized potential impact and AC were linearly aggregated into CI by in order not to underestimate their equal importance (Fritzsche, 2014).

(7) A hierarchical CA was performed using Ward's method to group the countries based on vulnerability index (VI) scores (Ward, 1963).

(8) A nonparametric correlation (Spearman's rank correlation) was run to determine the relationship between availability of legislation to establish an independent food safety authority, and AC and VI scores, respectively (Spearman, 1904).

2.2. Developing Impact Chains

Aim of developing impact chains is to set cause-effect relationships between extreme climatic events and potential food safety threats. For this purpose, case studies in the voluminous literature on the subject were used. In the case studies, extreme climatic events have been found to manifest itself as eight main pressures on food safety in the production phase through direct and indirect effects (Figure 2). However effect of each extreme event is not limited to one group of pressure, the eight pressures on food safety can be grouped in two as microbial (bacterial, viral, fungal and parasitic) and chemical contamination.

During production phase, human pathogens can contaminate crops and feed through water, soil, insects or other animals which are contaminated with faecal matter of animal or human origin while direct contact, spores, eggs or contaminated feed or water are transmission vehicles for animals (Bicudo & Goyal, 2003; Fenlon, Ogden, Vinten, & Svoboda, 2000; Tirado et al., 2010; Yeni et al., 2016). Extreme climatic events directly or indirectly cause one or more of these vehicles to be contaminated either with chemicals or microorganisms.

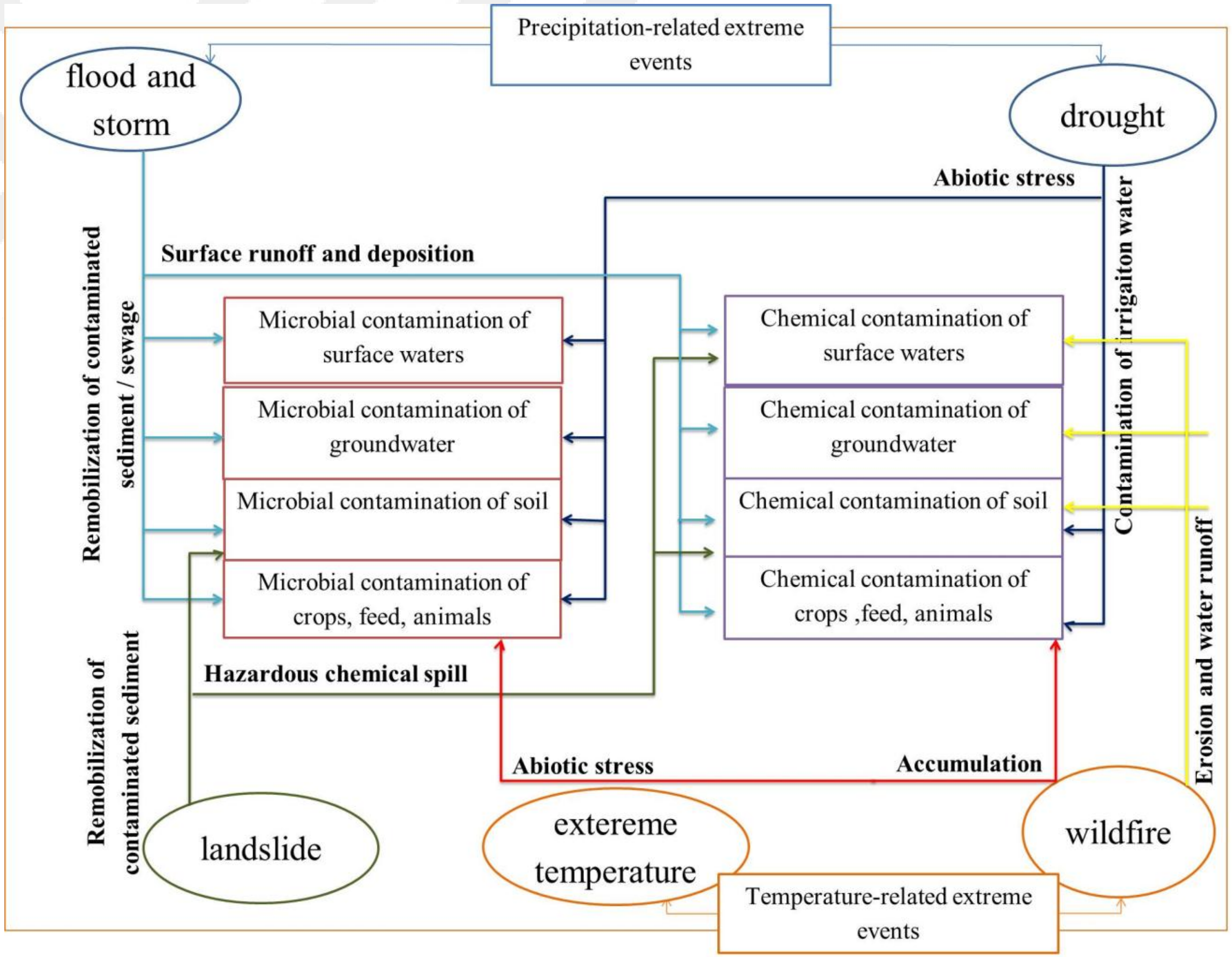

Figure 3 Impact chains demonstrating the extreme climatic events-related environmental pressures on food safet

It has been known that contaminated irrigation water is a route of crop contamination with microbial pathogens and surface runoff has got the leading role in driving pathogen load in surface waters (Levantesi et al., 2012). Beyond transferring the pathogen to the surface of crops, contaminated irrigation water may potentially contaminate the soil (Fatica & Schneider, 2011). It has been demonstrated by the case studies that there is a definite causal relationship between extreme precipitation-related weather events and waterborne diseases (Cann, Thomas, Salmon, Wyn-Jones, & Kay, 2013). Floods can be directly linked to contamination of food (both of plant and animal origin), soil, surface water, groundwater sources with foodborne pathogens and chemical cotamination of surface and groundwater, soil, feed and food products (crops, milk and meat) (Albering, van Leusen, Moonen, Hoogewerff, & Kleinjans, 1999; Alderman, Turner, & Tong, 2012; Auld, MacIver, & Klaassen, 2004; Casteel, Sobsey, & Mueller, 2006; Codling, 2009; Curriero, Patz, Rose, & Lele, 2001; Funari, Manganelli, & Sinisi, 2012; Jamieson, Gordon, Sharples, Stratton, & Madani, 2002; Lake et al., 2015; Marcheggiani et al., 2010; Rotkin-Ellman, Solomon, Gonzales, Agwaramgbo, & Mielke, 2010). Likewise, storms can be linked to microbial contamination with human pathogens and chemical contamination of surface waters, groundwater, soil and food product itself (Abel et al., 2010; Edwards, Harter, Fogg, Washburn, & Hamad, 2016; Fox, Chari, Resnick, & Burke, 2009; Jamieson et al., 2002; Johnson, Kimbrough, Lauenstein, & Christensen, 2009; Presley et al., 2006; Tom, Fletcher, & McCarthy, 2014), while drought is linked to using untreated sewage water or contaminated groundwater for irrigation in the absence of clean water which in turn may cause microbial contamination of the product, soil and groundwater as well as chemical contamination of food products and soil (Heikens, Panaullah, & Meharg, 2007; Nguyen-the et al., 2016). Soil contamination may lead to microbial internalization in food items after storm or drought events and this elevates the risk of foodborne outbreaks (Ge, Lee, & Lee, 2012). It is deduced from the studies that precipitation-related extreme events increase the likelihood of direct transmission of pathogens via faecal-oral route in humans and animals as well as indirect transmission of these pathogens after deposition on crops and soil (Marvin et al., 2013).

On the other hand, extremely hot temperatures together with drought can trigger mycotoxin formation on agricultural products (Daniel et al., 2011; Giorni, Magan, Pietri, Bertuzzi, & Battilani, 2007; Magan, Medina, & Aldred, 2011). This fact also holds true for feed contamination with mycotoxins which threatens the safety of livestock production (Romoser, Marroquin-Cardona, & Phillips, 2013). Along with feed contamination risk, extreme climatic events poses a more direct risk to well-being of livestock by poliferation of animal diseases which in turn increases the use of veterinary drugs and pesticides (Tirado et al., 2010). Elevated levels of temperature is also linked to chemical contamination of crops by causing heavy metal accumulation (Y. Li et al., 2013). Monitoring and evaluating the consequences of the extreme events as a whole seems esseantial because for example a combination of drought with high ambient temperatures may cause wildfires and it may in turn may cause some organic pollutants formed by incomplete combustion to contaminate food products by depositing into water or soil (Costopoulou et al., 2010). Likewise, soil erosion followed by a wildfire cause chemical contamination of soil, surface and groundwater (Mansilha, Carvalho, Guimaraes, & Marques, 2014; Santin, Doerr, Otero, & Chafer, 2015; Silva et al., 2015).

Since landslides are caused as a consequence of local geography and heavy precipitation events rather than being solely precipitation or temperature related, they are listed as a third group of extreme events. Landslide can be linked to chemical contanination of surface waters and microbial and chemical contamination of soil due to remobilization of contaminated sediments or hazardous chemical spills (Cunningham, 2005).

Apart from the aforementioned consequences related to food safety, the extreme climatic events also have direct implications on food security due to crop and animal losses and increase in the food prices especially in areas already facing undernourishment and food inadequacy (IPCC, 2014). Since the frame is limited to food safety theats, food security-related consequences of extreme events are not covered in this study.

2.3. Choosing Vulnerability Indicators

Since using discrete data violates the multivariate normal distribution assumption of PCA (Kolenikov & Angeles, 2009; Ng, 2015), solely variables presented as continuous data with global coverage were kept in the analysis. Ordinal and interval data were excluded from the study for the sake of consistancy of the composite index (CI). The data set (with no missing entries) for 26 indicators was gathered from International Disaster Database- Center for Research on the Epidemiology of Disasters (EM-DAT), Food and Agriculture Organization of the United Nations (FAO), and the World Bank (WB) for 118 countries. Original coverage of the study was downsized from 193 (sovereign member states of UN) to 118 due to lack of data. In order to eliminate the bias against the countries having broader lands, the indicators which can not be measured on percent or per capita scale were divided by the land area of individual countries on 10^6 km^2 scale. All exposure and sensitivity indicators were hypotized to have negative effect on vulnerability while adaptive capacity indicators have positive effect.

Selection of exposure indicators were based on the impact chains which were created upon the literature on the association of food safety incidents with extreme climatic events (i.e. wildfires, extreme temperature events, landslides, floods, storms, droughts). To be statistically sound and not to further downsize the number of countries, exposure data were collected for the period of 23 years (1993-2015). Also for substantial number of countries exposure data is not available before 1993 in the EM-DAT database (Table 1).

Table 1 Sources of Exposure Indicators

Name of the indicator (1993 – 2015)	Source
frequency of wildfires*	EMDAT
frequency of landslides*	EMDAT
frequency of floods*	EMDAT
frequency of storms*	EMDAT
frequency of droughts*	EMDAT
frequency of extreme temperature events (hot and cold)*	EMDAT

* These indicators were optimized by dividing by land area of each country in 10^6 km^2 scale in order the eliminate the bias against the countries having larger areas.

When it comes to selecting sensitivity indicators, several assumptions were made based on the following facts: Firstly, although the majority of foodborne pathogens do not have target populations, the risk groups which are primarily affected by infections are pregnant women, infants, elderly and immunocompromised adults (Forsythe, 2010). Secondly, prevalence of communicable diseases in a population could be a strong sign for the functionality of the existing healthcare system. Thirdly, since some small countries such as Puerto Rico, Malta and Mauritius barely have agricultural production, maintaining food safety during production phase could not be considered as a critical problem in such countries. And lastly, dietary diversity and undernourishment are strong proxies for access to food and food security which deepens the consequences caused by food safety threats. In consideration of these facts, it was hypothesized that higher levels of agricultural production, dependence of people on carbonhydrate-based diets, undernourishment, percentage of people prone to infections (population under the age of 14 and above the age of 65), and prevalence of communicable diseases in the population would increase the sensitivity of individual countries to food safety threats posed by climate change. Therefore the most recent data for the total of 11 sensitivity indicators were collected to provide a snapshot of the global sensitivity levels (Table 2).

Table 2 Sources of Sensitivity Indicators

Name of the indicator	**Description**	**Source**
Net Food Production Index (2013)	Relative level of the aggregate volume of food production (any disposable production for any use except as seed and feed) for each year in comparison with the base period 2004-2006.	FAO
Livestock (Meat and Poultry) Production (2014)*	Total meat and poultry production in tonnes.	FAO
Cereal Production (2014)*	Total cereal production in tonnes.	FAO
Fruit & vegetable production (2013)*	Total fruit & vegetable production in tonnes.	FAO
Cause of death, by communicable diseases and maternal, prenatal and nutrition conditions (% of total) (2012)	Cause of death refers to the share of all deaths for all ages by communicable diseases and maternal, prenatal and nutrition conditions including infectious and parasitic diseases, respiratory infections, and nutritional deficiencies such as underweight and stunting.	WB
% pop at age 65+ (2015)	Population ages 65 and above as a percentage of the total population	WB
% pop at age 14- (2015)	Population between the ages 0 to 14 as a percentage of the total population	WB
% Agricultural land area	Agricultural land refers to the share of land area that is arable, under permanent crops, and under permanent pastures	WB
Share of dietary energy supply derived from cereals, roots and tubers (%) (3-year average) (2011)	Percentage of the energy supply (in kcal/caput/day) provided by cereals, roots and tubers as a percentage of the total Dietary Energy Supply (DES) (in kcal/caput/day). This is a sign of quality of the diet.	FAO
Average Prevalence of undernourishment (%) (2013-2015)	Percentage of the population whose food intake is insufficient to meet dietary energy requirements continuously.	FAO
Food inadequacy (2015)	Percentage of the population that is at risk of not covering the food requirements associated with normal physical activity even though can not be considered chronically undernourished.	FAO

* These inidicators were optimized by dividing by land area of each country in 10^6 km^2 scale in order the eliminate the bias against the countries having larger areas.

Although the selected AC indicators do not embrace a full range of adaptive measures to mitigate the adverse effects of extreme climatic events and to reduce food safety threats, it was hypotized that infrastructure-related indicators such as availability of water for irrigation and sanitation, and accesibility to electricity and sanitation facilities have a direct role in minimizing the potetial impacts of extreme climatic events. Likewise, it was hypotized that life expectancy at birth and health expenditure were selected as a sign of at which level countries have the ability to combat potential health risks posed by food safety threats via extreme climatic events. Lastly, Gross Domestic Product (GPD) per capita, share of value added agriculture to GDP and government effectiveness were selected to provide the financial asset to how can adapative capacity measures be implemented. Overall, the most recent data for 9 adaptive capacity indicators were collected mostly from World Bank Database and it was hypothesized that all of the indicators would contribute positively to the index (Table 3).

Table 3 Sources of Adaptive Capacity Indicators

Name of the indicator	Description	Source
Average percentage of arable land equipped for irrigation (%) (2010-2012)	Percentage of agricultural areas purposely provided with water, including land irrigated by controlled flooding	FAO
Access to electricity, rural (% of population) (2012)	Percentage of rural population with access to electricity	WB
% Total population with access to improved water sources (2012)	Percentage of the population using an improved drinking water source including piped water on premises and other improved drinking water sources (public taps or standpipes, tube wells or boreholes, protected dug wells, protected springs, and rainwater collection)	WB
Access to improved sanitation facilities (%)(2012)	Percentage of the population using improved sanitation facilities (flush/pour flush, ventilated improved pit latrine, pit latrine with slab, and composting toilet) to ensure hygienic separation of human excreta from human contact	WB
GDP per capita (current US$) (2011)	Gross domestic product (the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products) divided by midyear population.	WB
Health expenditure, total (% of GDP) (2013)	sum of public and private health expenditure including the provision of health services (preventive and curative), family planning activities, nutrition activities, and emergency aid designated for health but does not include provision of water and sanitation.	WB
Agriculture, value added to GDP (%) (2012)	Share of agricultural sector in GDP with the net output of agricultural sector (forestry, hunting, and fishing, crop and livestock production) after adding up all outputs and subtracting intermediate inputs	WB
Life expectancy at birth, total (years) (2012)	Number of years a newborn infant would live if prevailing patterns of mortality at the time of its birth were to stay the same throughout its life	WB
Government effectiveness (2014)	Perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies.	WB

2.4. Normalizing Indicators

Since vulnerability analysis is a multivariate method, selected indicators are measured in different scales and thus should be normalized before running the analysis. Although there are different normalization methods such as standardization with z-scores, ranking etc., min-max standardization was chosen in this study. Because in this way, normalized indicator values range between 0-1 scale and negative values are avoided.

Collected indicators were normalized according to the min-max normalization method below:

$$indicator_{standardized} = \frac{indicator_{value} - indicator_{minimum}}{indicator_{maximum} - indicator_{minimum}}$$

Where, indicator $_{max.}$ and indicator $_{min.}$ are the minimum and maximum value of the indicator to be normalized.

2.5. Weighting Indicators

Since the indicators do not necessarily have equal influence on the respective component, there are a whole range of statistical (such as factor analysis, multiple regression and equal weighting) and participatory methods to assign weights to the variables. In this study, outputs of Principle Component Analysis (PCA) were used in order to calculate the weights of each indicator of each vulnerability component (namely exposure, sensitivity and adaptive capacity).

PCA was used as a tool to reveal the level of association between the variables by transforming them into a new set of uncorrelated variables using a correlation matrix (OECD, 2008). In this way, components were obtained which were smaller in number than variables and explain most of the variance among variables (Verma, 2013). In a way, these components served as a manifestation of relationships between observed variables, and thus gived a clue to the unobservable basis for their association.

Prior to performing the analysis, assumptions of PCA were checked whether the data was suitable enough to proceed. One of the assumptions underlying the formulation of the principal components is that the input variables are multivariate normal, or at least that normality is a reasonable distributional approximation (Kolenikov & Angeles, 2009; Ng, 2015). Since using descrete data (nominal and ordinal data) violates this normality assumption (Kolenikov and Angeles, 2004), solely variables presented as continious data were kept in the analysis. Another assumption is sampling adequacy which was tested with the Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy for the overall dataset. Since theoretically it is advised to proceed the analysis if KMO value is 0.60 or higher (Kaiser & Rice, 1974), this rule is obeyed in the analysis. The last assumption is suitability of the data for reduction and it was tested by the Bartlett's test of sphericity, which checks whether there are adequate number of correlation between variables. To this aim, if the significance level is lesser than 0.05 it was proceeded with the analysis in order to reject the null hypothesis which indicates that individual indicators are uncorrelated. Since the Bartlett's test is very sensitive to sampling size (Knapp & Swoyer, 1967), results of this test were considered together with the KMO value.

Although PCA is among the most preferred multivariate methods for deconstructing the original data structure in order to make it more interpretable, elements of subjectivity lie in judgements of the researchers in identifying the components (Bellmann, 2016). In order to minimize the subjectivity, firstly eigenvalues greater than 1.0 were kept in the analysis and then a parallel analysis was performed with 1000 repeats and 95% confidence interval to define the number of components to be drawn from the dataset according to the Monte Carlo Framework proposed by (O'Connor, 2000).

Secondly, assuming that the components are uncorrelated, Kaiser's varimax rotation technique was implemented in order to facilitate the interpretation of the components by minimizing the number of indicators that have a high loading on the same factor. Subsequent to extraction of the components, factor loadings over the value of 0.5 were used to calculate the weights for each indicator. The methodology proposed by Gomez-Limon and Riesgo for PCA was used in this study (Gomez-Limon & Riesgo, 2009).

Vulnerability component index (VCI) values are calculated according to the formula below:

$$VCII_j = \sum_{k=1}^{n} w_{kj}\, I_j$$

where, $VCII_j$ is vulnerability component index indicator, w is weight of indicator I is normalized indicator, j is number of principle component, and k is number of indicator.

The weights wk_j are derived from division of square of the factor loading to the related eigenvalue of each component:

$$wk_j = \frac{(factor\ loading)^2}{eigenvalue_j}$$

Vulnerability index component values are obtained from weighted aggregation of the vulnerability index component indicators by multiplying the related indicator by the percentage proportion of the eigenvalue of the related component:

$$VC = \sum_{j=1}^{m} \alpha_j\, VCII_j$$

where, VC is the value of vulnerability component, j is the number of principle component, VCII is intermediate agricultural vulnerability indicator, α is weight applied to intermediate agricultural vulnerability indicator. This weight is calculated as below:

$$\alpha_j = \frac{eigenvalue_j}{\sum_{j=1}^{m} eigenvalue_j}$$

The normalized indicators were then multiplied with the assigned weights to calculate the vulnerability component values. Using the formula above, exposure, sensitivity and adaptive capacity indices were calculated. Since largest factor loadings are assigned to the individual indicators having the largest variation across cases, this is a desirable property for making cross-country comparisons (OECD, 2008).

2.6. Aggregating Vulnerability Components

A linear aggregation method was performed to aggregate the three vulnerability components to form the vulnerability index by using the formula:

$$VI = PI - AC$$

where, VI is the vulnerability index, PI is potential impact (Exposure + Sensitivty) and AC is the adaptive capacity value for each country. PI and AC values were normalized using min-max normalization method prior to calculation in order to make sure they have equal effect on the index value, and V values were normalized with the same method in order to have the results between 0-1 scale.

2.7. Grouping Countries

Cluster analysis is a way to examine data sets to assess whether or not that data set can be summarized in a meaningful manner that the data resembling each other are grouped together (Everitt, 2011). There are different clustering methods such as agglomerative, divisive or non-hierarchical (k mean clustering), the most widely used method for clustering is Ward's hierarchical method (Orsi, 2017). In hierarchical clustering method, the following steps are followed: first, a data matrix is formed where there are the same number of clusters with the number of cases, secondly, optionally the data matrix is standardized, thirdly, a resemblance coefficient is calculated to identify the similarities among cases, and then finally, a dendogram is produced based on the clustering method used in order to reveal the hierarchy of similarities among cases (Romesburg, 2004).

In this study, in order to have a complete understanding of how countries were grouped together into non-overlapping clusters by their respective vulnerability values, hierarchical clustering method was applied using Ward's method (Ward, 1963) and squared euclidean distance function to determine the distance between clusters. . Cluster groups were visually shown on the map to see how countries are scattered around the World.

2.8. Correlating Vulnerability Index with Legal Status

Pearson's correlation coefficient (R) is used to quantify the strength of of a linear relationship between data sets but this method is very sensitive to outliers and fails to detect a nonlinear relationship (Borradaile, 2003). Therefore, a nonparametric method was chosen to quantify the strength of the correlation between the continious and ordinal data sets in this study. A 2-tailed Spearman's rank correlation (Spearman, 1904) was run to determine the measure of association of the ordinal dummy variable assigned for availability of legislation to establish a food safety authority in each country and normalized adaptive capacity scores and normalized vulnerability index scores, respectively. Legislation data was collected from the FAOLEX database of Food and Agriculture Organisation and dummy variables were assigned based on the following scale: 0=there is no authority, 0,5=there is an authority but not independent, 1=there is an independent food safety authority.

CHAPTER 3

RESULTS OF VULNERABILITY AND CLUSTER ANALYSES

In this chapter, firstly, outcomes of the vulnerability analysis as exposure, sensitivity, adaptive capacity and vulnerabiliy index. Secondly, based on the scores of these indices, outcomes of the cluster analysis were presented. And with the help of clusters, country performances in terms of exposure levels to extreme climatic events, level of sensitivity to these events, adaptive capacity level to decrease these sensitivities, and overall vulnerability to extreme climatic events in the frame of food safety were discussed. Finally, outcomes of the non-parametric correlation between availabiliy of legislation to establish a food safety authority in each county, and AC/VI scores were evaluated.

3.1. Exposure Levels

In order to construct the exposure index, a PCA was conducted with 6 indicators. Normalized exposure indicator values were listed in the Table A1 in the Appendix section. As a prerequisite for conducting the PCA, selected indicators have to have correlation among them. Table 4 domonstrates that there were sufficient correlation among selected indicators. Availability of correlation among variables also quantified by the Bartlett’s test of sphericity, and if the significance level is lesser than 0.05 it was proceeded with the analysis in order to reject the null hypothesis which indicates that individual indicators are uncorrelated. Since the Bartlett’s test is very sensitive to sampling size (Knapp & Swoyer, 1967), results of this test were considered together with the KMO value. Another prerequisite for PCA is Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy in order to continue with the analysis with enough sample size. Although KMO was very under the level of 0.60

for exposure index (Kaiser & Rice, 1974), analysis was carried out because the value was very close to the minimum level and the significance of the Bartlett's test was below the value of 0,5 (Table5).

Table 4 Correlation Matrix for Exposure Indicators

Number of extreme climatic events per land area	# of wildfires	# of landslides	# of floods	# of storms	# of droughts	# of Extreme temperature events
# of wildfires	1,000	-,091	,022	-,036	,015	,193
# of landslides	-,091	1,000	,399	,071	,181	,042
# of floods	,022	,399	1,000	,511	,519	,190
# of storms	-,036	,071	,511	1,000	,810	,114
# of droughts	,015	,181	,519	,810	1,000	,027
# of Extreme temperature events	,193	,042	,190	,114	,027	1,000

Table 5 Principal components extracted to build the PCA for exposure

Components	Rotation sum of squared loadings		
	Total (eigenvalue)	% of variance	Cumulative %
E_1	2,131	35,521	35,521
E_2	1,273	21,216	56,737
E_3	1,215	20,254	76,990
Kaiser-Meyer-Olkin measure of sampling adequacy=0.587			
Bartlett's test of sphericity χ^2 = 201.341 df=15 p =0.000			
Components	Parallel Analysis Results		
	Raw data eigenvalues	Mean	Percentile random data eigenvalues
E_1	2,363	1,313	1,452
E_2	1,202	1,159	1,244
E_3	1,055	1,042	1,107

Components were gathered from the PCA based on several criteria. First, number of components above the eigenvalue greater than 1 were taken into account. According to this criterion, three components had to be extracted. And, these three components account for 77 % of the total variance (Table 5). Secondly, scree plot was examined and the point in the curve was spotted where the tail of the curve started to tail off. According to this second criterion, two components could be extracted from the analysis (Figure 4). Thirdly, a Monte Carlo simulation (parallel analysis) was carried out with 1000 repeats and 95% confidence interval. According to the results of parallel analysis, there had to be only one component (Table 5). Based on these criteria, three components were gathered from a total of 6 indicators in order not to discard more than one indicator.

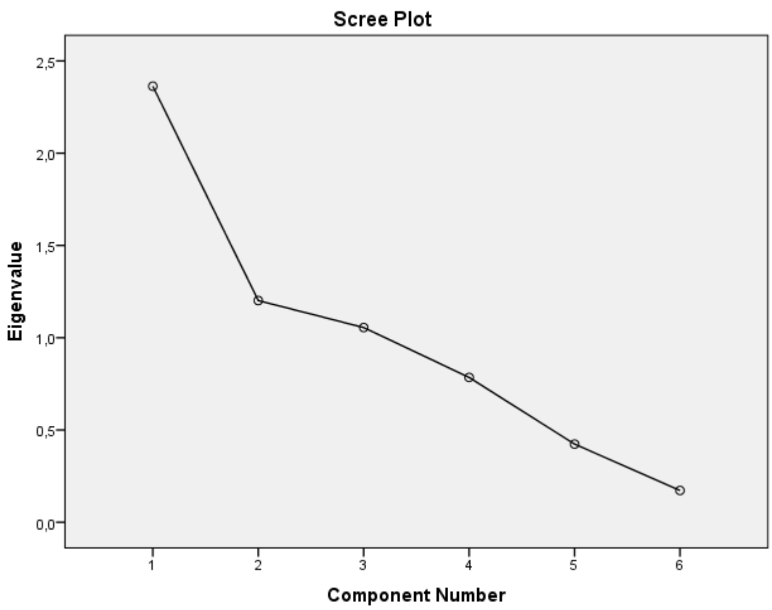

Figure 4 Scree Plot Extracted from the PCA analysis for E Index

After components were extracted from the PCA, the next step was rotating the data to decrease the number of components which have high loading on the same component. To this aim, varimax rotation method was used and resulting rotated correlation matrix was presented in the Table 6. According to rotated correlation matrix, 3 indicators loaded on the first component (number of storms, number of floods, and number of droughts), while 1 indicator loaded on the second component alone (number of landslides), and two indicators loaded on the third component (number of wildfires and number of extreme temperature events). This loadings reveal that precipitation-related extreme climatic events loaded on the first component, temperature-related extreme events loaded on the third component and landslides did not fell into one of these components because landslides can not occur solely due to precipitation or temperature changes but specific geographical charasteristics of an area lead to a permanent inclination for this event.

Table 6 Rotated Component Matrix for the Exposure

Indicator	**Component**		
	1	2	3
# of storms (1993-2015)/Land area (10^6 km^2)	,943	,009	,015
# of droughts (1993-2015)/Land area (10^6 km^2)	,928	,088	-,018
# of floods (1993-2015)/Land area (10^6 km^2)	,614	,562	,170
# of landslides (1993-2015)/Land area (10^6 km^2)	,039	,926	-,057
# of Extreme temperature events (1993-2015)/Land area (10^6 km^2)	,042	,212	,770
# of wildfires (1993-2015)/Land area (10^6 km^2)	,000	-,217	,767

In the next step, communality values were examined. Since PCA is a data reduction technique based on variances, communalities are important in this analysis because they represent the proportion of variance of each variable that can be explained by selected components. Any indicator below the communality value below 0,5 has to be excluded from the analysis. However, all the communalities were above 0,5 in the PCA and no indicator was removed from the analysis (Table 7). Component plot in the rotated space for exposure component visiually showing the distibution and grouping of indicators can be seen in the Figure A1 in the Appendix section.

Table 7 Communalities for the Exposure Indicators

Indicator	Initial	Extraction
# of wildfires (1993-2015)/Land area (10^6 km^2)	1,000	,636
# of landslides (1993-2015)/Land area (10^6 km^2)	1,000	,862
# of floods (1993-2015)/Land area (10^6 km^2)	1,000	,722
# of storms (1993-2015)/Land area (10^6 km^2)	1,000	,889
# of droughts (1993-2015)/Land area (10^6 km^2)	1,000	,870
# of Extreme temperature events (1993-2015)/Land area (10^6 km^2)	1,000	,640

All indicators are contributing to index in the direction as was hypothesized. Weights of indicators revealed that major contributor of the exposure index is precipitation-related extreme events while temperature-related extreme events and landslides contributed almost equally (Figure 5).

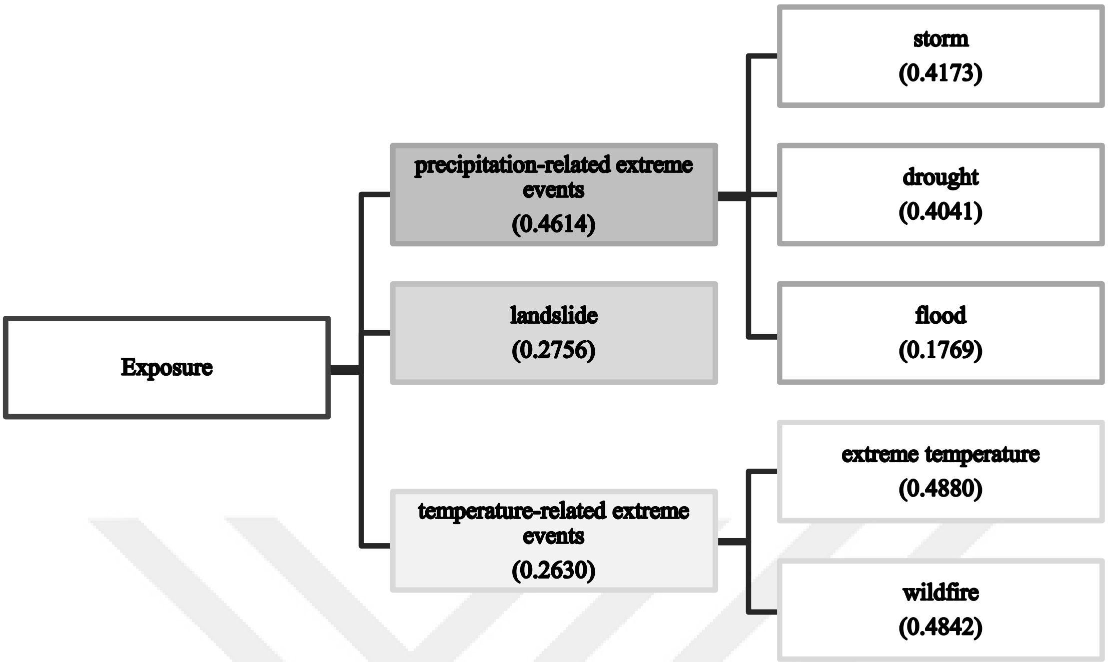

Figure 5 Structure of aggregate exposure index

Normalized exposure index scores are shown in ascending order in Table 8 and on the map in Figure 6. Cluster analysis results were demonstrated in the Figure A2 in the Appendix section. According to the scores, Malta and United Arab Emirates have the lowest amount of exposure while Mauritius faces the highest exposure levels. It can be seen from the clustering that more than half of the countries, including the majority of the Northern countries, face very low exposure levels while only 14% of the countries face moderate to high exposure. The reason why mostly small countries having high exposure levels can be that the exposure indicators were divided by total land area of the country in order to eliminate the bias against the countries having broader lands. Apart from that, the reason behind Mauritius having distinctively the highest exposure level is the country being ranked first at storm and drought, and ranked third at flood frequencies despite facing no wildfires, extreme temperatures or landslides. Other countries in the high exposure subcluster are mostly small tropical-climate countries which ranked among the top 10 at precipitation-related extreme events and landslides. The other countries in the subcluster are Switzerland, Cyprus and Nepal. Switzerland is the 4th country in the exposure ranking due to frequent landslides, storms and extreme temperature events. This may be explained by the big altitude differences in the country together with the biome diversity despite its small land area. Likewise, Nepal is the 9^{th} country in the ranking due to frequent landslides, flood and extreme temperature events. Cyprus is the 6^{th} country in the list due to temperature-related extreme events. The country, Cyprus, was ranked 1^{st} in the extreme temperature events, 2^{nd} in wildfires, and 5^{th} in droughts.

Table 8 Cluster groups for exposure scores

Cluster 1		Cluster 2	
Very low Exposure 0-0,087	***Low Exposure*** 0,088-0,27	***Moderate Exposure*** 0,28-0,44	***High Exposure*** 0,45–1
Malta, UAE, Finland, Canada, Mongolia, Suriname, Kazakhstan, Norway, Russia, Botswana, Egypt, Sweden, Australia, Algeria, Congo, Mali, Mauritania, Brazil, Tunisia, Uzbekistan, Namibia, Ghana, Ukraine, Argentina, Zambia, Venezuela, Iran, Kuwait, Cote d'Ivoire, Cameroon, Tanzania, USA, South Africa, Morocco, Nigeria, Madagascar, Lao, Ethiopia, Mozambique, Saudi Arabia, Chile, China, Belarus, Denmark, Paraguay, Mexico, Jordan, Bolivia, Uruguay, Peru, Cambodia, Spain, Turkey, Estonia, Kenya, India, France, Togo, Germany, Colombia, Poland, Thailand, Latvia, Georgia UK, Malaysia	Indonesia, Armenia, Pakistan, Uganda, Hungary, Lithuania, Ecuador, Cuba, Afghanistan, Czech R., Greece, Italy, Nicaragua, Japan, Malawi, Panama, Lesotho, Kyrgyzstan, Portugal, Viet Nam, Romania, Lebanon, Honduras, Slovenia, Bulgaria, Slovakia, Austria, Swaziland, Dominican R., Albania, Moldova, Bosnia and Herzegovina, Croatia, Costa Rica Netherlands	Fiji, Tajikistan, Senegal, Macedonia, Guatemala, Belgium, Philippines, Sri Lanka, Bangladesh	Nepal, Trinidad and Tobago, Cyprus, Jamaica, Switzerland, El Salvador, Rwanda, **Mauritius**

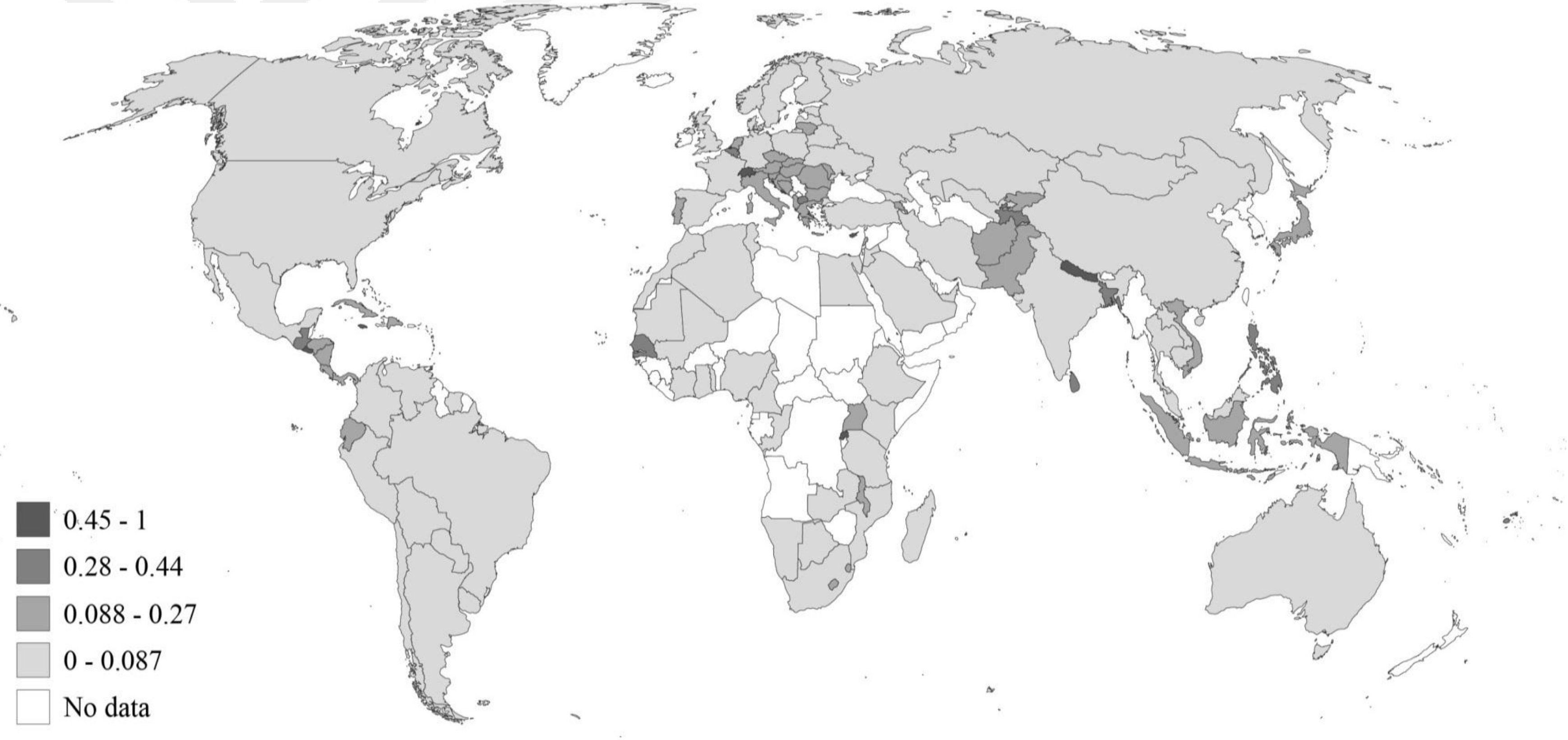

Figure 6 Exposure index shown on the world map

Exposure levels of 118 countries grouped into 4 as very low (0-0.087), low (0.088-0.27), moderate (0.28-0.44), and high (0.45-1) based on the results of cluster analysis. Countries with no data were shown in white

3.2. Sensitivity Levels

In order to construct the sensitivity index, a PCA was conducted with 11 indicators. Normalized sensitivity indicator values can be seen in the Table A2 in the Appendix section. As a prerequisite for conducting PCA, selected indicators have to have correlation among them. Table 9 domonstrates that there were sufficient correlation among selected sensitivity indicators. Availability of correlation among variables also varified by the Bartlett's test of sphericity because the significance level is lesser than 0.05. Another prerequisite for PCA is Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy in order to continue with the analysis with enough sample size. And KMO measure of sampling adequacy value was high above the level of 0.60 for sensitivity index (Kaiser & Rice, 1974) for the analysis to be carried out.

In the next step, communality values were examined to check the proportion of variance of each variable that was explained by selected components. Any indicator below the communality value below 0,5 has to be excluded from the analysis. However, all the communalities were above 0,5 in thi PCA and no indicator was removed from the analysis (Table 10). Component plot in the rotated space for sensitivity component visiually showing the distibution and grouping of indicators can be seen in the Figure A3 in the Appendix section.

Table 9 Correlation Matrix for Sensitivity Indicators

Correlation	**Net Food Production Ind.**	**Livestock Prod.**	**Cereal Prod.**	**Fruit & vegetable Prod.**	**% of Cause of death**	**% pop at age (65+)**	**% pop at age (14-)**	**% of Agricultural land**	**Share of dietary en. supply**	**Prev. of undernourishment**	**Food inadeq.**
Net Food Production Index (2013)	1,000	-,141	-,139	-,112	,459	-,538	,557	,004	,514	,414	,439
Livestock Primary	-,141	1,000	,155	,556	-,231	,155	-,216	-,316	-,202	-,209	-,197
Cereal Production	-,139	,155	1,000	,351	-,264	,363	-,320	-,153	-,054	-,182	-,201
Fruit & vegetable production	-,112	,556	,351	1,000	-,198	,121	-,155	-,257	-,118	-,162	-,165
Cause of death	,459	-,231	-,264	-,198	1,000	-,689	,905	,214	,714	,688	,698
% pop at age 65+	-,538	,155	,363	,121	-,689	1,000	-,836	-,122	-,723	-,523	-,602
% pop at age 14-	,557	-,216	-,320	-,155	,905	-,836	1,000	,191	,735	,675	,704
% of Agricultural land	,004	-,316	-,153	-,257	,214	-,122	,191	1,000	,186	,151	,145
Share of dietary en. supply (%)	,514	-,202	-,054	-,118	,714	-,723	,735	,186	1,000	,553	,601
Prevalence of undernourishment (%)	,414	-,209	-,182	-,162	,688	-,523	,675	,151	,553	1,000	,976
Food inadequacy	,439	-,197	-,201	-,165	,698	-,602	,704	,145	,601	,976	1,000

Table 10 Communalities for the Sensitivity Indicators

	Initial	Extraction
Net Food Production Index (2013)	1,000	,428
Livestock Primary (Meat+Poultry) (tonnes) (2014)/Agricultural land (sq. km)	1,000	,620
Cereal Production (tonnes) (2014)/Agricultural land (sq. km)	1,000	,285
Fruit & vegetable production (tonnes) (2013) / agricultural land (km^2)	1,000	,702
Cause of death, by communicable diseases and maternal, prenatal and nutrition conditions (% of total)	1,000	,796
% pop at age 65+ (2015)	1,000	,719
% pop at age 14- (2015)	1,000	,873
Agricultural land (% of land area) (2013)	1,000	,347
Share of dietary energy supply derived from cereals, roots and tubers (%) (3-year average) (2011)	1,000	,682
Average Prevalence of undernourishment (%) (2013-2015)	1,000	,685
food inadequacy (2015)	1,000	,741

Components were gathered from the PCA based on several criteria. First, number of components above the eigenvalue greater than 1 were taken into account. According to this criterion, two components had to be extracted. And, these two components account for 63 % of the total variance (Table 11). Secondly, scree plot was examined and the point in the curve was spotted where the tail of the curve started to tail off. According to this second criterion, two components could be extracted from the analysis (Figure 7). Thirdly, a monte carlo simulation (parallel analysis) was carried out with 1000 repeats and 95% confidence interval. According to the results of parallel analysis, again there had to be two component (Table 11). Based on these criteria, two components were gathered from a total of 11 indicators.

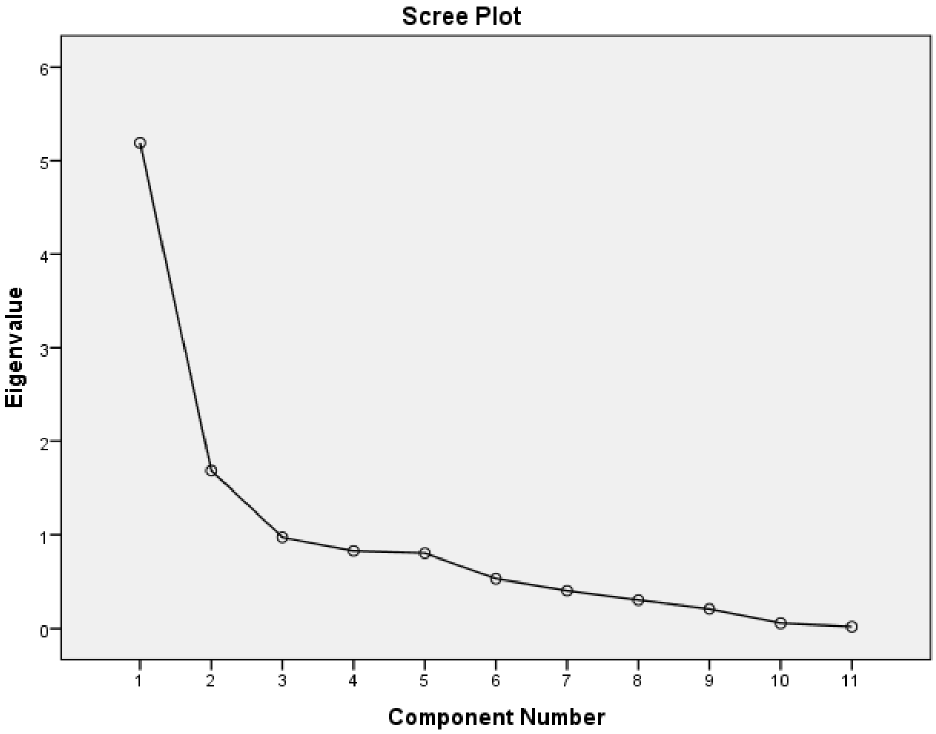

Figure 7 Scree Plot Extracted from the PCA analysis of Sensitivity Component

Table 11 Principal components extracted to build the PCA for sensitivity

Components	Rotation sum of squared loadings		
	Total (eigenvalue)	% of variance	Cumulative %
S_1	4,832	43,928	43,928
S_2	2,045	18,588	62,516
Kaiser-Meyer-Olkin measure of sampling adequacy = 0.767			
Bartlett's test of sphericity χ^2 =1066.236 df=55 p =0.000			
Components		Parallel Analysis Results	
	Raw data eigenvalues	Mean	% random data eigenvalues
S_1	5,189	1,531	1,679
S_2	1,688	1,370	1,476

After components were extracted from the PCA, the next step was rotating the data to decrease the number of components which have high loading on the same component. To this aim, varimax rotation method was used and resulting rotated correlation matrix was presented in the Table 12. According to rotated correlation matrix, 7 indicators loaded on the first component (% of population under the age of 14, % of deaths due to communicable diseases and maternal, prenatal and nutrition conditions, food inadequacy, % of population above the age of 65, share of dietary energy supply derived from cereals, roots and tubers, average Prevalence of undernourishment, and net food production index), while 4 indicators loaded on the second component (cereal production, primary livestock production, fruit and vegetable production, and % of agricultural land area). This loadings revealed that there were two distinct group of indicators. One of which was related to Population-related sensitivities, and the other one was related to production.

Table 12 Rotated Component Matrix for the Sensitivity Indicators

Indicator	Component	
	1	2
% pop at age 14- (2015)	,916	-,183
Cause of death, by communicable diseases and maternal, prenatal and nutrition conditions (% of total)	,865	-,217
food inadequacy (2015)	,848	-,147
% pop at age 65+ (2015)	-,837	,131
Share of dietary energy supply derived from cereals, roots and tubers (%) (3-year average) (2011)	,821	-,090
Average Prevalence of undernourishment (%) (2013-2015)	,813	-,154
Net Food Production Index (2013)	,654	-,028
Fruit &vegetable production (tonnes) (2013) / agricultural land (km^2)	-,031	,837
Livestock Primary (Meat+Poultry) (tonnes) (2014)/Agricultural land (km^2)	-,097	,781
Agricultural land (% of land area) (2013)	,082	-,583
Cereal Production (tonnes) (2014)/Agricultural land (km^2)	-,208	,491

a. Extraction Method: Principal Component Analysis. Rotation converged in 3 iterations.

The absolute values of the weights revealed that population-related sensitivities contributed much more to the sensitivity index than production-related sensitivities (Figure 8). Among population-related component, indicators have almost equal influences on the component score. Among production-related sensitivity component, fruit and vegetable production together with livestock production have the higher influence on the component score when compared to cereal production and percentage of agricultural land. This may be the consequence of the fact that while fresh produce and meat-related food safety incidents can not be halted, mycotoxin formation, which is was major food safety threat related to cereals, has been mostly kept under control since strict limits were set by national and international legislation (Yeni et al., 2016).

Most of the indicators of sensitivity contributed to index in the direction as hypothesized except for percentage of population above 65 and percentage of agricultural land area. Because top ranks of the indicator percentage of population above 65 is mainly occupied by the Northern countries unlike the rest of the component. Likewise, top ranks of the indicator percentage of agricultural land is occupied by the Southern countries while agricultural production per land area is mainly dominated by the Northern countries due to the industrialized agricultural production systems in these countries.

Normalized sensitivity index scores were shown in ascending order in Table 13 and on the map in Figure 9. Dendogram demonstrating the cluster analysis results for sensitivity index can be seen in the Figure A4 in the Appendix section. According to the scores, United Arab Emirates have the lowest amount of sensitivity score while Zambia faces the highest sensitivity. It can be seen from the clustering that almost half of the countries, including all of the Northern countries, has low to moderate sensitivity scores while only one third of the countries face high to very high sensitivity. The reason behind the countries having the highest sensitivity scores is the food security problem in these countries together with population under age of 14 and cause of death by communicable diseases and maternal, prenatal and nutrition conditions. However, the other subclusters are not homogeneous as the highest sensitivity subcluster, it can be deduced from the clustering that as sensitivity levels decrease, population under the age of 14, food security and health-related problems decrease while population above the age of 65 increases irrespective of agricultural production.

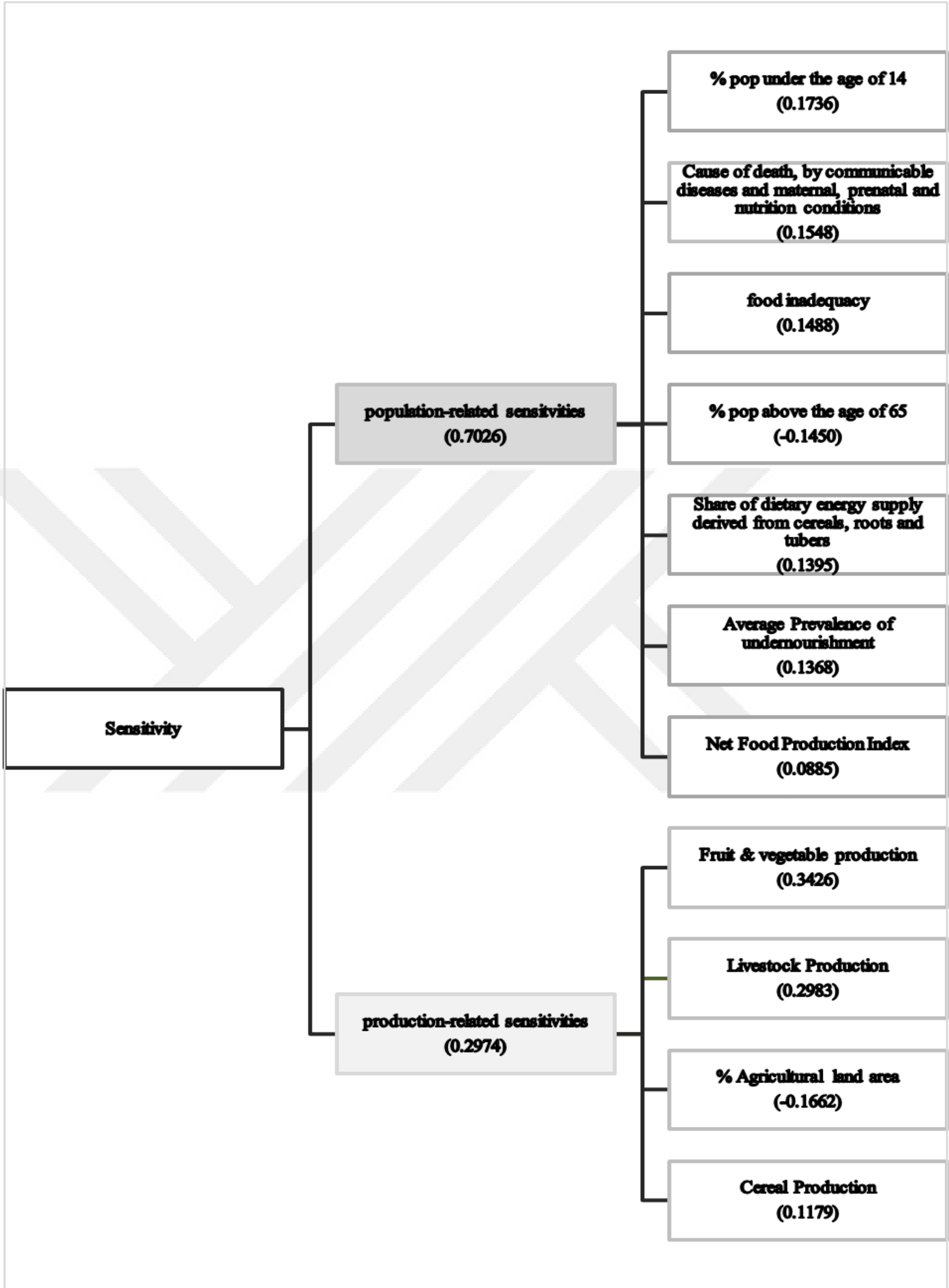

Figure 8 Structure of aggregate sensitivity index
Numbers in parenthesis are the weights obtained from principal component analysis.

Table 13 Cluster groups for sensitivity scores

Cluster 1		Cluster 2	
Low Sensitivity (0-0,24)	***Moderate Sensitivity*** (0,25-0,40)	***High Sensitivity*** (0,41-0,69)	***Very High Sensitivity*** (0,70-1)
UAE, Canada, Switzerland, Cyprus, Sweden, Slovakia, Norway, Finland, Australia, Russia, Austria, Croatia, USA, Slovenia, Latvia, Macedonia, Czech R, Belarus Moldova, Spain, Hungary, Brazil, Estonia, Chile, Germany, Bosnia and Herzegovina, Cuba, Fiji, Greece, Lithuania, Venezuela, Poland, Albania, France, Portugal, Argentina, Iran, UK, Romania, Kazakhstan, Bulgaria, Denmark, Malaysia, Saudi Arabia, Italy, Mexico, Colombia, Ukraine, Armenia, Georgia, Costa Rica, Kuwait, Tunisia, Turkey, Belgium, Lebanon	Mauritius, Algeria, China, Kyrgyzstan, Uruguay, Jamaica, Panama, Ecuador, Jordan, Netherlands, Thailand, Japan, Morocco, Suriname, Uzbekistan, Peru, Honduras, Dominican R, Trinidad and Tobago, Paraguay, El Salvador, Indonesia, Malta, Nicaragua, South Africa	Mongolia, Viet Nam, Mauritania, Bolivia, Nepal, Sri Lanka, Philippines, India, Pakistan, Guatemala, Ghana, Senegal, Cameroon, Egypt, Cambodia, Mali, Botswana, Lao, Nigeria, Cote d’Ivoire, Lesotho, Togo, Bangladesh, Tajikistan, Kenya	Uganda, Swaziland, Namibia, Afghanistan, Congo R, Tanzania, Madagascar, Rwanda, Malawi, Ethiopia, Mozambique, **Zambia**

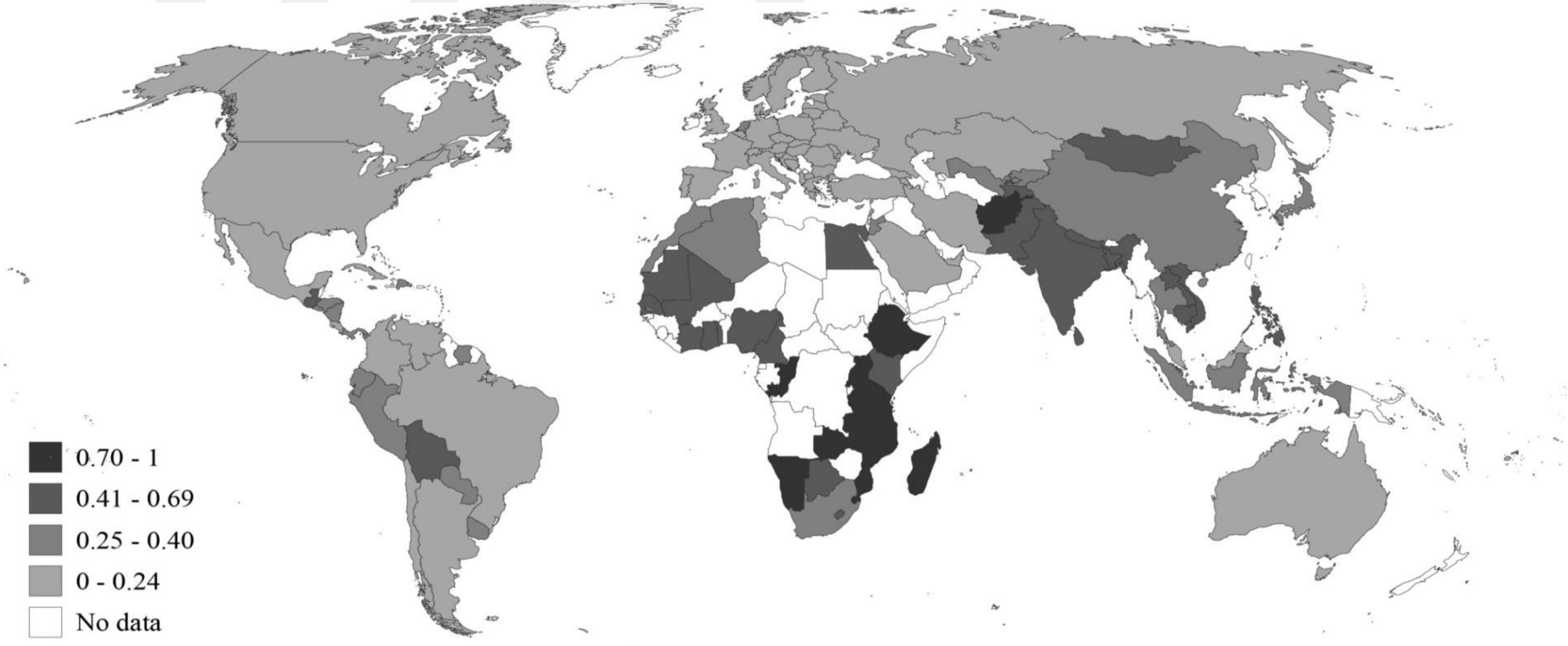

Figure 9 Sensitivity index shown on the world map

Sensitivity levels of 118 countries grouped into 4 as low (0-0.24), moderate (0.25-0.40), high (0.41-0.69), and very high (0.70-1) based on the results of cluster analysis. Countries with no data were shown in white.

3.3. Adaptive Capacity Levels

In order to construct the sensitivity index, a PCA was conducted with 9 indicators. Normalized adaptive capacity indicator values can be seen in the Table A3 in the Appendix section. As a prerequisite for conducting PCA, selected indicators have to have correlation among them. Table 14 domonstrates that there were sufficient correlation among selected sensitivity indicators. Availability of correlation among variables also varified by the Bartlett's test of sphericity because the significance level is lesser than 0.05 (Table 15). Another prerequisite for PCA is Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy in order to continue with the analysis with enough sample size. And KMO measure of sampling adequacy value was high above the level of 0.60 for sensitivity index (Kaiser & Rice, 1974) for the analysis to be carried out (Table 15).

In the next step, communalitiy values were examined to check the proportion of variance of each variable that was explained by selected components. Any indicator below the communality value below 0,5 has to be excluded from the analysis. However, all the communalities were above 0,5 in thi PCA and no indicator was removed from the analysis (Table 16). Component plot in the rotated space for adaptive capacity component visiually showing the distibution and grouping of indicators can be seen in the Figure A5 in the Appendix section.

Table 14 Correlation Matrix for AC Indicators

Correlation	Access to IWS	Access to ISF	GDP per capita	Health exp.	Life exp. at birth	Govern. eff.	Access to electricity	Arable land eq. for irrigation	Agr. VA to GDP
Access to IWS	1,000	,826	,473	,260	,747	,671	,823	,181	,753
Access to ISF	,826	1,000	,516	,262	,836	,658	,893	,271	,728
GDP per capita	,473	,516	1,000	,509	,606	,745	,414	-,050	,559
Health exp.	,260	,262	,509	1,000	,325	,435	,170	-,240	,271
Life exp. at birth	,747	,836	,606	,325	1,000	,700	,815	,222	,628
Govern. eff.	,671	,658	,745	,435	,700	1,000	,568	-,058	,690
Access to electricity	,823	,893	,414	,170	,815	,568	1,000	,350	,668
Arable land eq. for irrigation	,181	,271	-,050	-,240	,222	-,058	,350	1,000	,053
Agr. VA to GDP	,753	,728	,559	,271	,628	,690	,668	,053	1,000

Components were gathered from the PCA based on several criteria. First, number of components above the eigenvalue greater than 1 were taken into account. According to this criterion, two components had to be extracted (Table 15). And, these two components account for 76 % of the total variance. Secondly, scree plot was examined and the point in the curve was spotted where the tail of the curve started to tail off. According to this second criterion, two components could be extracted from the analysis (Figure 10). Thirdly, a monte carlo simulation (parallel analysis) was carried out with 1000 repeats and 95% confidence interval. According to the results of parallel analysis, again there had to be two component (Table 15). Based on these criteria, two components were gathered from a total of 9 indicators.

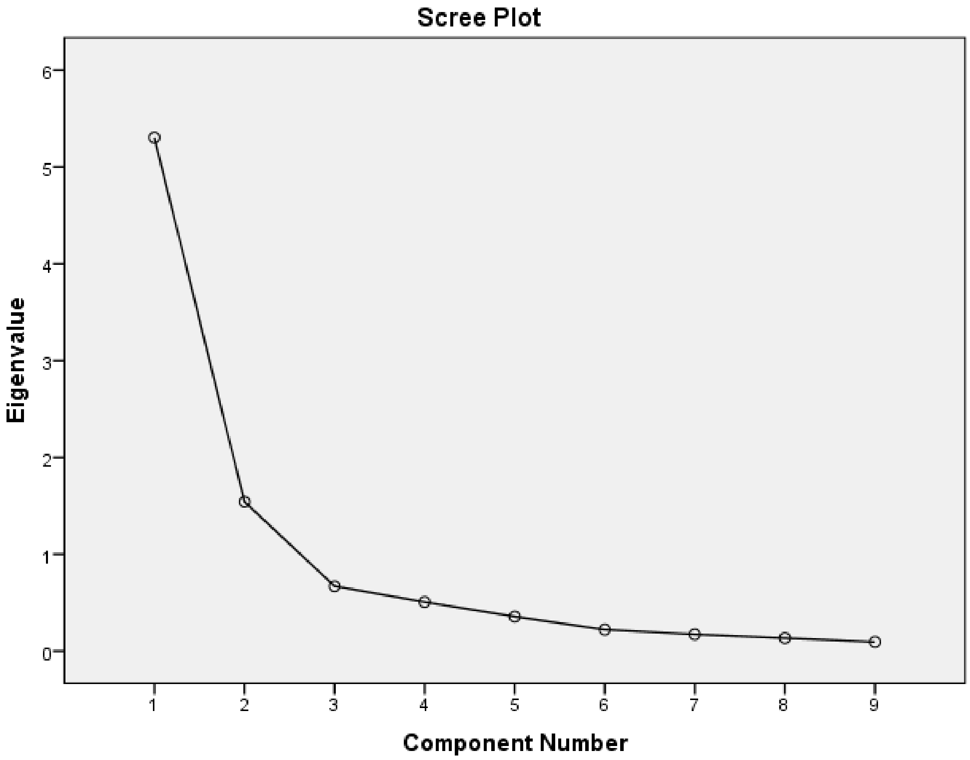

Figure 10 Scree Plot Extracted from the PCA analysis of AC Component

Table 15 Principal components extracted to build the PCA for adaptive capacity

Components	Rotation sum of squared loadings		
	Total (eigenvalue)	% of variance	Cumulative %
AC_1	5,059	56,215	56,215
AC_2	1,786	19,840	76,055
Kaiser-Meyer-Olkin measure of sampling adequacy = 0.886			
Bartlett's test of sphericity χ^2 =865.400 df=36 p =0.000			
Components	Parallel Analysis Results		
	Raw data eigenvalues	Percentile random data eigenvalues	
AC_1	5,303052	1,579453	
AC_2	1,541921	1,393947	

Table 16 Communalities for the Sensitivity Indicators

	Initial	Extraction
% Total population with access to improved water sources (2012)	1,000	,808
Access to improved sanitation facilities (%)(2012)	1,000	,887
GDP per capita (current US$) (2011)	1,000	,699
Health expenditure, total (% of GDP) (2013)	1,000	,620
Life expectancy at birth, total (years) (2012)	1,000	,812
Government effectiveness (2014)	1,000	,791
Access to electricity, rural (% of population) (2012)	1,000	,880
Average percentage of arable land equipped for irrigation (%) (2010-2012)	1,000	,655
Agriculture, value added to GDP (%) (2012)	1,000	,694

After components were extracted from the PCA, the next step was rotating the data to decrease the number of components which have high loading on the same component. To this aim, varimax rotation method was used and resulting rotated correlation matrix was presented in the Table 17. According to rotated correlation matrix, 6 indicators loaded on the first component (% of total population with access to improved water sources, % of total population with access to improved sanitation facilities, life expectancy at birth, government effectiveness, % of total rural population with access to electricity, and value added agriculture to GDP), while 3 indicators loaded on the second component (GDP per capita,% of total arable land equipped for irrigation, and health expenditure). This loadings revealed that there were two distinct group of indicators. One of which was related to infrastructure and governance-related adaptive capacity indicators, and the other one was related to economy.

Table 17 Rotated Component Matrix for AC Indicators

	Component	
	1	2
% of total population with access to improved water sources (2012)	,895	,078
% of total population with access to improved sanitation facilities (2012)	,941	,023
GDP per capita (current US$) (2011)	,585	,597
Health expenditure, total (% of GDP) (2013)	,240	,750
Life expectancy at birth, total (years) (2012)	,891	,136
Government effectiveness (2014)	,733	,504
Access to electricity, rural (% of population) (2012)	,930	-,119
Average percentage of arable land equipped for irrigation (%) (2010-2012)	,374	-,717
Agriculture, value added to GDP (%) (2012) (inverted data)	,797	,243

a.Rotation Method: Varimax with Kaiser Normalization. Rotation converged in 3 iterations.

The weights obtained from PCA revealed that infrastructure and governance-related assets contributed much more to the adaptive capacity index than economy-related assets (Figure 11).

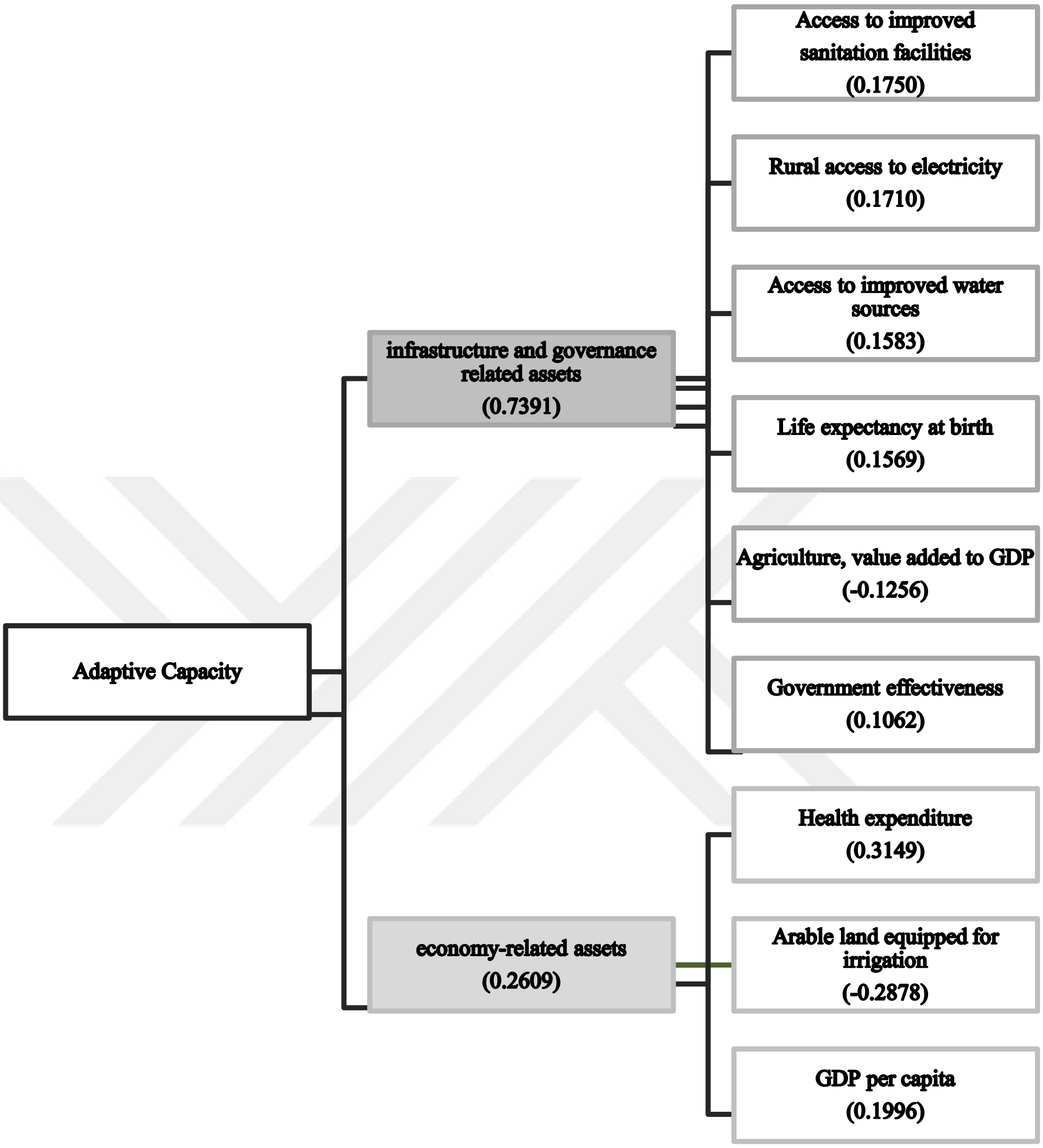

Figure 11 Structure of aggregate adaptive capacity index
Numbers in parenthesis are the weights obtained from principal component analysis.

Most of the indicators contributed to the index in the direction as was hypothesized except for average percentage of arable land equipped for irrigation. Because while top ranks of rest of the indicators were dominated by the Northern countries, there found no such homogeneous trend for the indicator average percentage of arable land equipped for irrigation. Normalized adaptive capacity index scores are shown in ascending order in Table 18 and on the map in Figure 12. Dendogram showing the clustering of countries can be seen in the Figure A6 in the Appendix section. According to the scores, Japan has the highest adaptive capacity score while Ethiopia has the lowest. It can be seen from the clustering that the vast majority of the countries, including all of the Northern countries, has high to very high levels of adaptive capacity scores while only 31% of the countries face low to moderate adaptive capacity levels. The countries having low adaptive capacity scores have low scores in each indicator. The reason behind the countries having the moderate adaptive capacity scores can be listed as dependency of economy on agricultural sector, which in turn may limit the infrastructure development due to lack of technology, low to medium level of life expectancy at birth, limited implementation of the policies due to low to medium level of government effectiveness, low levels of Gross Domestic Product (GDP) and, lastly lack of equipment for irrigation on agricultural lands.

Table 18 Cluster groups for adaptive capacity scores

Cluster 1		Cluster 2	
Low AC	***Moderate AC***	***High AC***	***Very High AC***
0-0,27	0,28- 0,59	0,60-0,78	0,79-1
Ethiopia, Togo, Mali, Mozambique, Tanzania, Madagascar, Kenya, Nigeria, Mauritania, Cambodia, Uganda, Afghanistan, Cote d'Ivoire, Malawi, Cameroon	Rwanda, Ghana, Zambia, Congo R, Lao, Senegal, Lesotho, Nepal, Swaziland, Namibia, Mongolia, Nicaragua, India, Bangladesh, Bolivia, Pakistan, Botswana, Tajikistan, Fiji, Honduras, Indonesia, Guatemala	Paraguay, Philippines, S. Africa, Morocco, El Salvador, Moldova, Kyrgyzstan, Peru, Algeria, Viet Nam, Uzbekistan, Armenia, Albania, Dominican R, Belarus, Sri Lanka, Jamaica, Venezuela, Russia, Ukraine, Panama, Egypt, Tunisia, Kazakhstan, Colombia, Thailand, Iran, China, Ecuador, Brazil, Romania, Bosnia and Herzegovina, Macedonia, Argentina, Bulgaria, Suriname	Turkey, Latvia, Mexico, Lithuania, Malaysia, Uruguay, Trinidad Tobago, Cuba, Lebanon, Poland, Estonia, Hungary, Mauritius, Croatia, Saudi Arabia, Jordan, Slovakia, Costa Rica, Czech R, Georgia, Slovenia, Kuwait, Finland, Malta, UK, Greece, Cyprus, Spain, Portugal, Belgium, Australia, UAE, Italy, Chile, Canada, Austria, Sweden, France, Germany, Denmark, Norway, USA, Netherlands, Switzerland, **Japan**

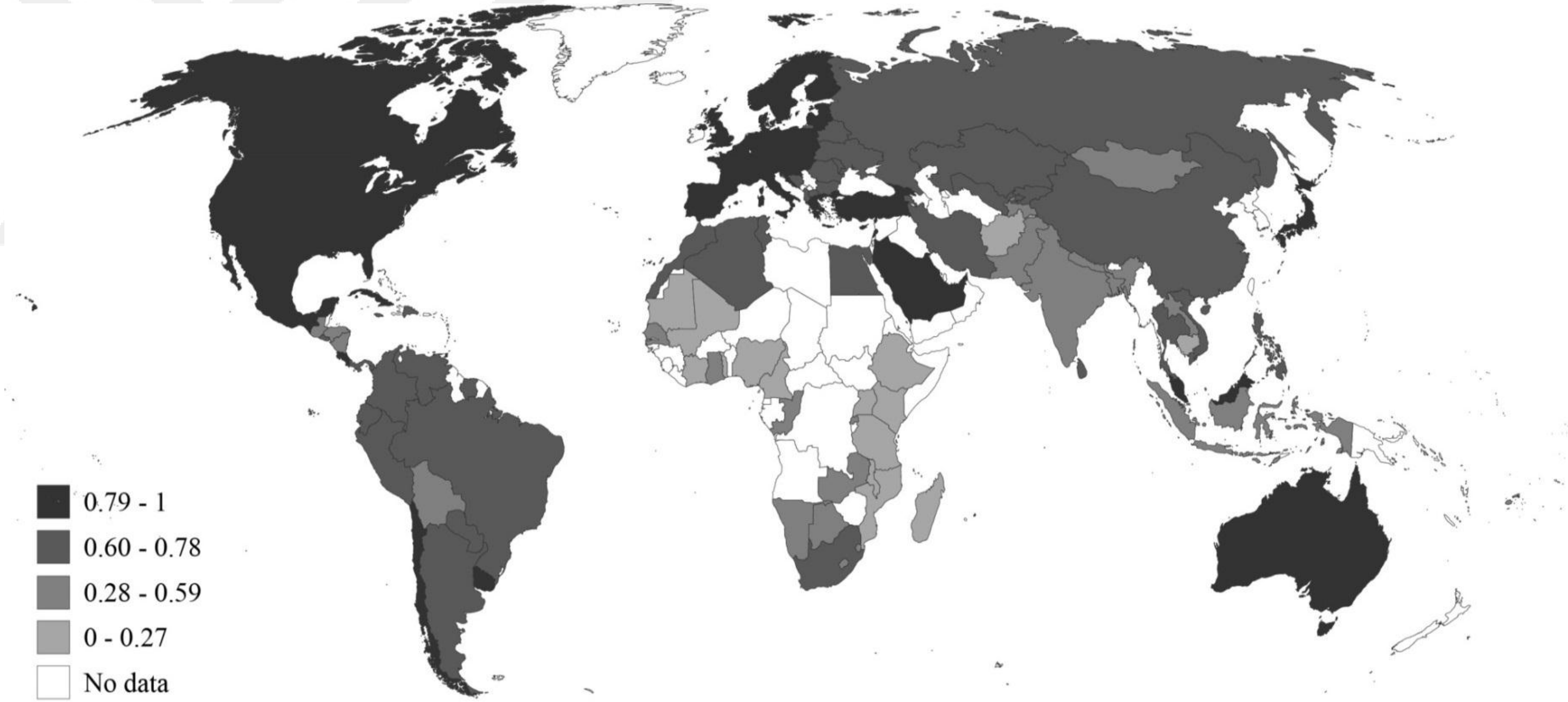

Figure 12 Adaptive Capacity index shown on the world map

Adaptive capacity levels of 118 countries grouped into 4 as low (0-0.27), moderate (0.28-0.59), high (0.60-0.78), and very high (0,79-1) based on the results of cluster analysis. Countries with no data were shown in white.

3.4. Vulnerability Index

Vulnerability index scores were based on the exposure, sensitivity and adaptive capacity indices. With aggregation of these indices, a normalized vulnerability index score was obtained for each of the 118 countries analyzed. Normalized vulnerability index scores can be seen in the Table A4 in the Appendix section. Based on these VI scores, a cluster analysis was run. Dendogram showing the results of this cluster analysis can be seen in the Figure A7 in the Appendix section. According to the vulnerability index scores, Rwanda is the most vulnerable country while United Arab Emirates is the least (Table 19). It can be seen from the clustering that all of the Northern countries has low vulnerability scores while the high and very high vulnerability cluster is solely occupied by the Southern countries (Figure 13). Remarkably, countries with very high sensitivity and low adaptive capacity despite low exposure levels dominate the very high vulnerability cluster. Among this cluster, only Rwanda has a high exposure score coupled with very high sensitivity and moderate adaptive capacity. Rest of the high vulnerability cluster is composed of countries having differential levels exposure and adaptive capacity but moderate to very high level of sensitivity. On the contrary, low vulnerability cluster is composed of the Northern countries having very low to low exposure, low to moderate sensitivity and high to very high adaptive capacity levels. The exceptions are Switzerland and Cyprus having high exposure, and Belgium having moderate exposure.

The countries in the moderate vulnerability cluster has moderate to high adaptive capacity levels, low to high sensitivity and very low to low exposure levels. Only exceptions are Macedonia, Sri Lanka, Fiji, Trinidad and Tobago and Jamaica with moderate to high exposure levels. The countries in this cluster may easily be better off by decreasing sensitivity levels via implementing targeted adaptive capacity policies.

Table 19 Cluster groups for vulnerability index scores

Cluster 1		Cluster 2	
Low VI	***Moderate VI***	***High VI***	***Very High VI***
0-0,25	0,26-0,50	0,51-0,75	0,76-1
UAE, Norway, Canada, USA, Sweden, Australia, Finland, Chile, Denmark, Spain, Germany, France, Austria, UK, Kuwait, Greece, Italy, Portugal, Slovenia, Japan, Czech R, Estonia, Saudi Arabia, Malta, Georgia, Poland, Brazil, Slovakia, Latvia, Hungary, Russia, Netherlands, Argentina, Jordan, Mexico, Iran, Cuba, Kazakhstan, Malaysia, Lithuania, Belarus, Venezuela, Croatia, Turkey, Uruguay, Tunisia, Switzerland, Ukraine, China, Colombia, Lebanon, Suriname, Costa Rica, Romania, Cyprus, Belgium, Bulgaria	Bosnia and Herzegovina, Thailand, Algeria, Ecuador, Armenia, Uzbekistan, Panama, Macedonia, Albania, Peru, Moldova, Morocco, Kyrgyzstan, S. Africa, Egypt, Paraguay, Dominician R., Viet Nam, Fiji, Indonesia, Honduras, Trinidad and Tobago, Mongolia, Bolivia, Jamaica, Botswana, Nicaragua, India, Sri Lanka, Pakistan	Philippines, Guatemala, Mauritius, Namibia, Ghana, El Salvador, Tajikistan, Lao, Mauritania, Cameroon, Lesotho, Congo R, Swaziland, Cote d'Ivoire, Senegal, Cambodia, Bangladesh, Nepal, Nigeria	Mali, Kenya, Uganda, Afghanistan, Zambia, Malawi, Tanzania, Togo, Madagascar, Mozambique, Ethiopia, **Rwanda**

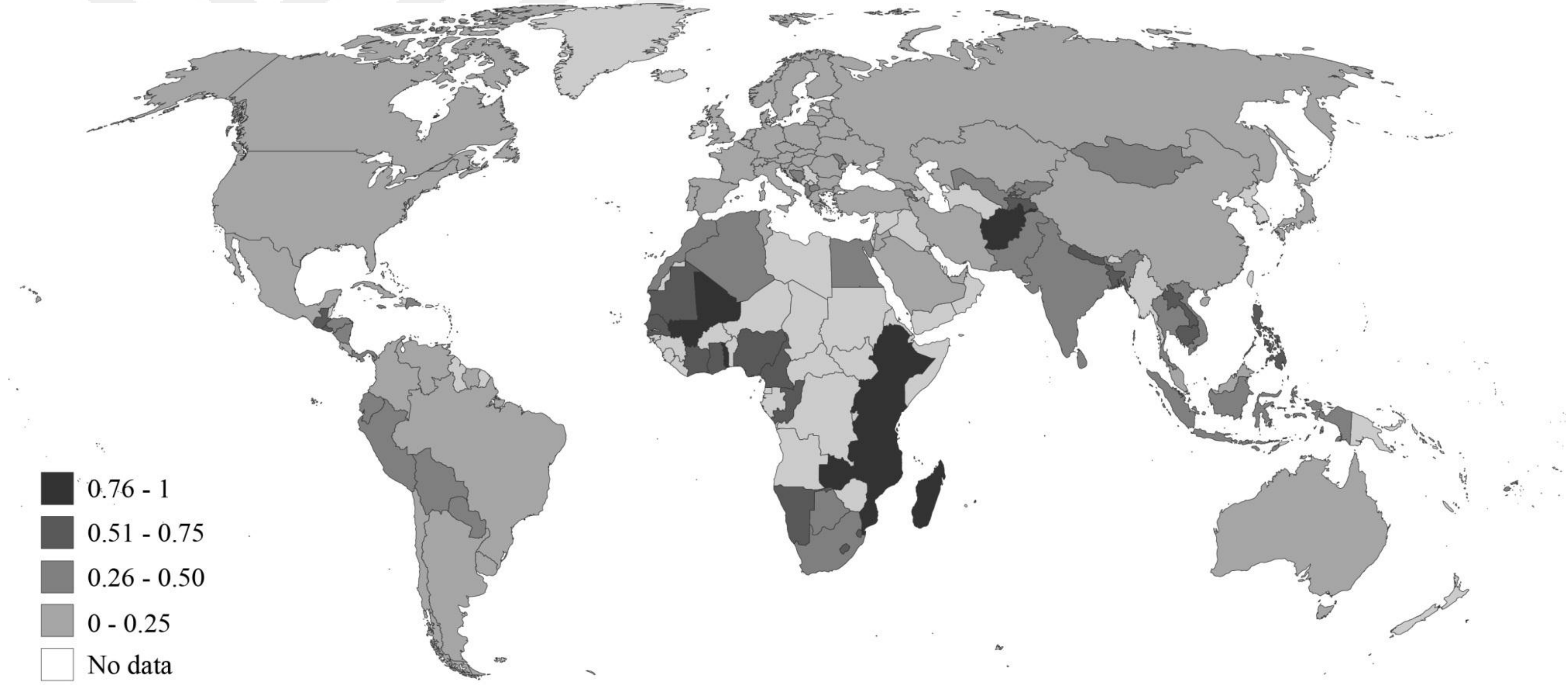

Figure 13 Vulnerability Index shown on the world map

Vulnerability levels of 118 countries grouped into 4 as low (0-0,25), moderate (0.26-0.50), high (0.51-0.75), and very high (0.76-1) based on the results of cluster analysis. Countries with no data are shown in white.

Figure 14 indicates that half of the countries were subject to low vulnerability level and one fourth of the countries were subject to moderate vulnerability level. However, only one fourth of the 118 countries analyzed were subject to high to very high vulnerability levels and these countries were solely comprised of the Southern countries. Moreover, only ten percent of the total of 118 countries analyzed were subject to very high vulnerability cluster. This distribution suggests a feasible adaptation option to in favor of the countries in this ten percent cluster because vulnerability level of these countries can be relatively easily decreased solely by increasing sensitivity levels without having to make any intervention to decrease exposure levels.

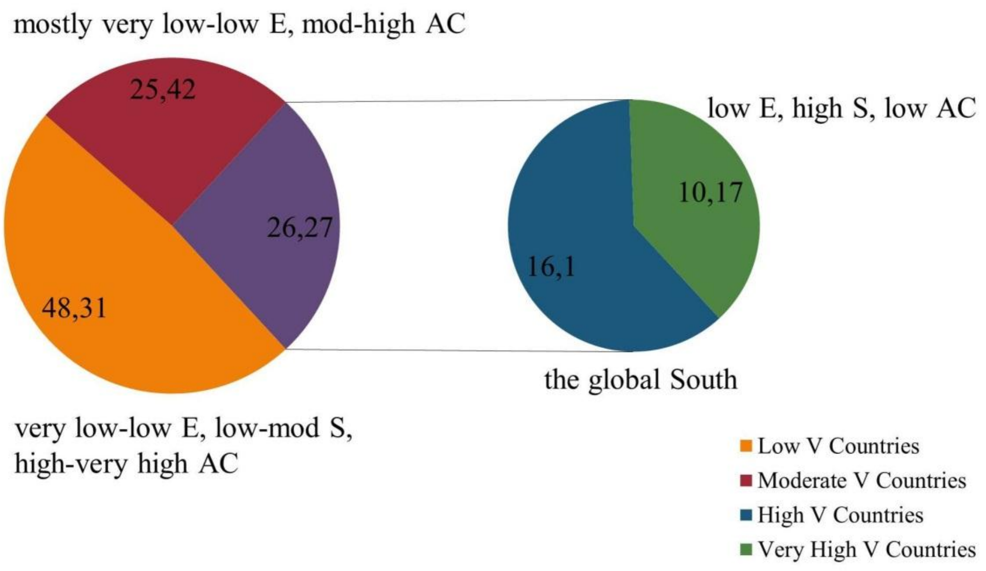

Figure 14 Distribution of countries according to cluster analysis scores

3.5. Role of Independent Food Safety Institutions

Although governments adopt the regulations and develop policies, institutions are the legal entities paving the way for implementing regulations by providing incentives, creating awareness, establishing protocols and guidelines, allocating resources, building infrastructure and enabling communication among stakeholders. In this sense, as well as establishing a national food safety authority, ensuring its independence seems crucial in order to facilitate a robust holistic approach in food safety management by minimizing overlapping responsibilities and weaknesses in surveillance and enforcement. Percentages of in-place independent food safety authorities in each vulnerability cluster indicates a correlation (74% for low vulnerability cluster, 47% for moderate vulnerability cluster, 26% for high vulnerability cluster, and 25% for very high vulnerability cluster). The moderate correlation between availability of an independent food safety authority and adaptive capacity and vulnerability index scores can be interpreted as these institutions serve as a stimulant for building an effective food safety management environment under the constraint of funding, regulation and enforcement (Figure 15 and 16).

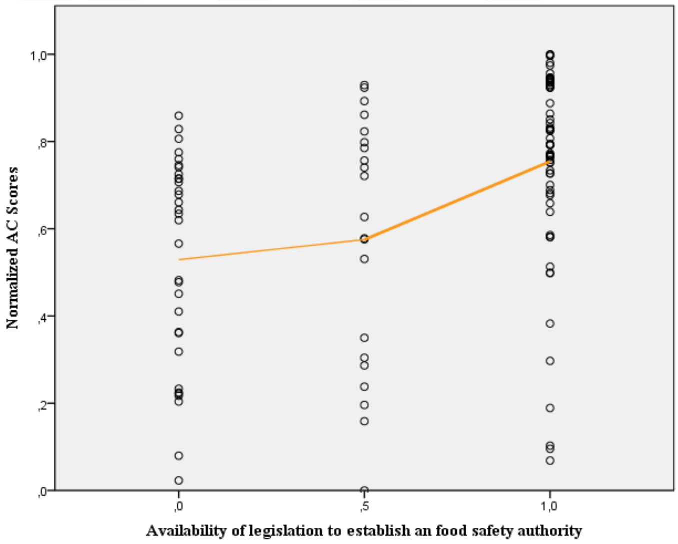

Figure 15 Nonparametric correlation between AC and Availability of Legislation

Results suggest that there is a moderate correlation which was statistically significant (rs= 0.451, N=118) between adaptive capacity index and legislation status.

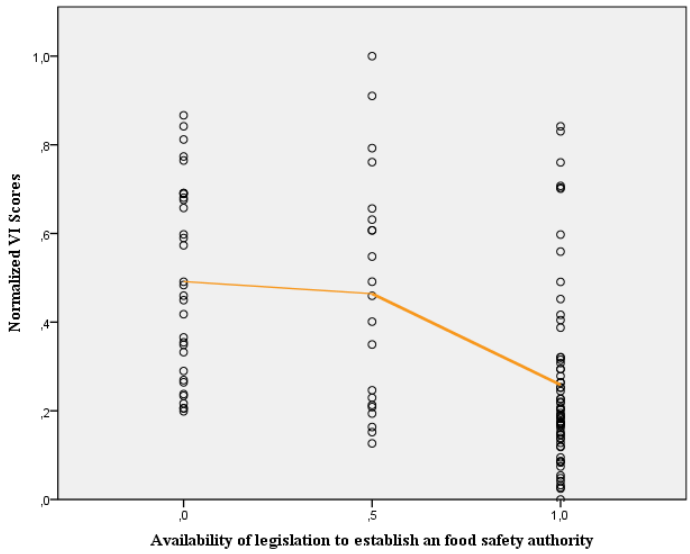

Figure 16 Nonparametric correlation between VI and Availability of Legislation

Results suggest that there is a moderate correlation which was statistically significant (rs=-0.489, p = .000, N=118) between vulnerability index and legislation status.

CHAPTER 4

DISCUSSION AND CONCLUSION

There is a trend reported by IPCC that the frequency and/or intensity of the extreme climatic events have been increasing, and duration of some extreme events has been changing substantially. Food production is particularly vulnerable against such large-scale changes in patterns of extreme climatic events because food safety incidents often originate in the early stages of food supply chain (Jooste, 2008; Norrung & Buncic, 2008; Yeni et al., 2016). Therefore, an explorative vulnerability analysis on a global scale was conducted in the face of extreme climatic events, focusing primarily on food production stage in order to reveal current vulnerabilities and to discuss adaptation options to propose a holistic solution. Country performances were compared by constructing a composite index. Although CIs are recognized as useful tools in identifying trends and providing simple comparison of countries in highly complex issues (Munda & Nardo, 2009; OECD, 2008), choosing relevant data and the right methods for data imputation and aggregation are crucial while the choice of normalization and weighting methods are less of a concern to ensure that the index is conceptually and statistically coherent (Santeramo, 2015a). In this study, vulnerability analysis was performed with no missing data, and only continious variables kept in the analysis in order not to violate the multivariate normal distribution assumption of PCA (Kolenikov & Angeles, 2009; Ng, 2015). A weighted aggregation method was used based on the weights from the PCA analysis for exposure, sensitivity and AC indices. However, linear aggregation method was used to construct vulnerability index in order not to underestimate the equal importance PI and AC.

Main limitation of the composite index constructed in this study appears as conceptual coherence due to lack of food safety related data such as prevalence of food safety management systems, occurrence of foodborne outbreaks. However, to facilitate the discussion on food safety, impact chains and data on independent food safety authorities were integrated into the study. In literature, extreme climatic events and food safety related studies either focus on attribution of food safety incidents to extreme climatic events via case studies as reviewed in the impact chains section (Albering et al., 1999; Alderman et al., 2012; Auld et al., 2004; Cann et al., 2013; Edwards et al., 2016; Funari et al., 2012; Ge et al., 2012; Mansilha et al., 2014; Nguyen-the et al., 2016; Rotkin-Ellman et al., 2010; Silva et al., 2015; Tom et al., 2014), or use participatory methods instead of vulnerability assessments due to lack of relevant data (Kirezieva et al., 2015; Semenza, Suk, Estevez, Ebi, & Lindgren, 2012). Nonetheless, other studies using vulnerability assessment as a tool focuses on food security notion via crop and livestock losses (Antwi-Agyei, Fraser, Dougill, Stringer, & Simelton, 2012; Z. Wang, Liao, He, & Fang, 2013). Consequently, including our study, discussions on outputs of composite indices and vulnerability analysis need to be considered as hypotheses rather than definitive conclusions considering the complexity of the realm of climate vulnerability and safety of food production, and the limited nature of available indicators in terms of relevance (Barré, 2001; Hoskins et al., 2015).

According to the results of the present study, which was designed to provide a firm underpinning for adaptation planners, one sixth of the 118 countries analyzed were subject to high level of exposure (0.45-1) while one third of them were subject to high to very high level of sensitivity (0.41-1) and low to moderate level of adaptive capacity (0-0.59). Results also suggest that irrespective of the exposure levels, countries having high sensitivity but low adaptive capacity levels are comprised of the Southern countries. Taking into account that only 14% of the countries out of 118 analyzed face moderate to high exposure levels, to adopt measures in order to minimize the devastating effects of extreme events in these small countries seems reasonable. Also, considering that precipitation-related extreme events are the major contributor of exposure index and, as can be deduced from the impact chains, they have a greater potential to microbiologically and chemically contaminate soil, food products, surface and groundwaters when compared to the other extreme events; it is also reasonable to primarily focus on the adaptation options targeting precipitation-related extreme events. To this end, the most promising adaptation option can be establishing early warning systems for all precipitation-related extreme events, and establishing climate-smart irrigation infrastructure especially in countries prone to drought. Sampling soil, surface and groundwater after an extreme event and monitoring water sources regularly for chemical and microbiological contamination (Kirezieva et al., 2015), and protecting groundwater from contamination by locating drywells considering local land use and subsurface conditions and monitoring quality and quantity of influent water (Edwards et al., 2016) may be an appropriate adaptation option for countries prone to both precipitation-related extreme events and landslides. Moreover, while mapping of risk areas for each extreme climatic event is a basic necessity for every country, training farmers for the risk of mycotoxin formation is particularly important for the Southern countries.

Apart from these measures to reduce the negative physical effects of extreme events, reducing sensitivities arising from population or production-related performance of countries requires another set of adaptation strategies. Since population-related sensitivities contributed much more to the sensitivity index than production-related ones, adaptation efforts can be focused on reducing the vulnerabiliy of the population. Food security-related problems, expanding population structure and lack of basic public health services appear as the driving forces behind population-related sensitivities. Considering that all of these driving forces, most notably food security, are closely tied to poverty (IPCC, 2014) and countries having high to very high sensitivity levels mostly have low to moderate levels of adaptive capacity, establishing international mechanisms to provide fiscal support is essential in order to improve feasibility of above-mentioned adaptation strategies. However, since infrastructure and governance-related assets contributed much more to the adaptive capacity index than economy-related assets, providing the fiscal support along with proper enforcement strategies to improve government effectiveness appear as a basic necessity.

Moreover, attempts of individual countries to completely stave off food safety threats have been of little avail because every country produces food for the global market. Therefore, establishing an independent food safety authority in each country together with a solid enforcement mechanism, surveillance plan and sufficient funding by available international institutions may facilitate implementation of proposed adaptation options and may serve as a stimulant for building an effective food safety management environment in the short term. In this way, overlapping responsibilities of ministries of health and agriculture, which are the major institutions which are in charge of food safety governance in most countries (Yeni, Acar, Soyer, & Alpas, 2017), can be minimized.

From a global point of view, a stepwise approach may be followed for defining the medium and long term strategies. In the medium term, implementation of private standards outside the global value chains can be promoted by including the extreme climate-related adaptation options in the standards through solid fiscal mechanisms to support the Southern countries. And, in the long term, negotiating a framework convention on food covering both safety and security of food from farm to table and blending available public and private standards via effective implementation and fiscal mechanisms to create incentives for the Southern countries may be the ultimate holistic approach to ensure safety of the global food market. Because in the context of food governance, ensuring food safety throughout the food supply chain requires a systems approach, which not only encompass the main stakeholders, namely producers, processors, retailers, policy makers and consumers and the relationships involved between these agents, but also include the functional institutional mechanisms focusing on environmental and economic aspects of global food system (Pinstrup-Andersen & Watson, 2011). However, since international institutions and national state governments have been underinvesting in public goods such as agricultural research, food science and rural infrastructure together with public law, which does not prioritize trade aspect of food supply, (von Braun, 2008) harmonizing all the public and private standards does not seem like a plausible solution in the near future. As private standards' capacity to ensure food safety extends beyond the public law, promoting implementation of these standards outside the global value chains, especially in the national food markets of the Southern countries, and including the extreme climate related adaptation options in these standards through solid international fiscal mechanisims may be a solution until solving the problem once and for all via a systems approach. Current situation is both unstable and likely to change in the near future because environmental and food security-related problems have continued to be unabated (Busch, 2011).

As a final remark, the recommendation of this study is that in order to ensure conceptual coherence of future assessment, the availability of data especially on food safety related indicators, such as prevalence of food safety management systems, occurrence of foodborne outbreaks, with global coverage has to be increased.

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APPENDIX

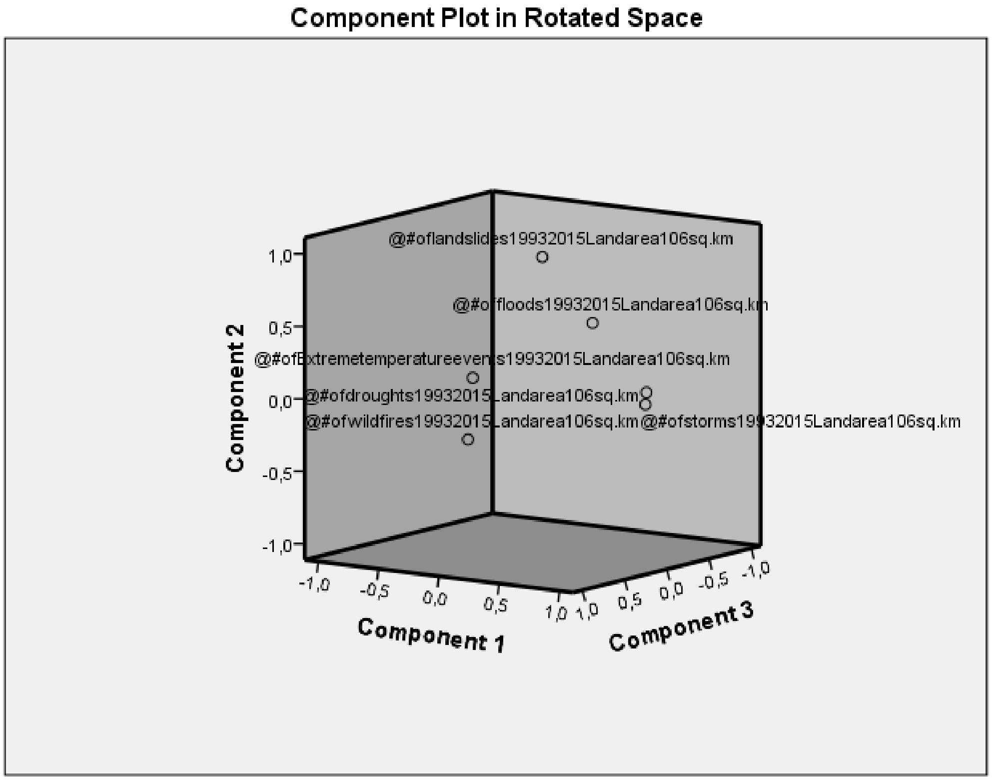

Figure A 1 Component Plot in the Rotated Space for E Component

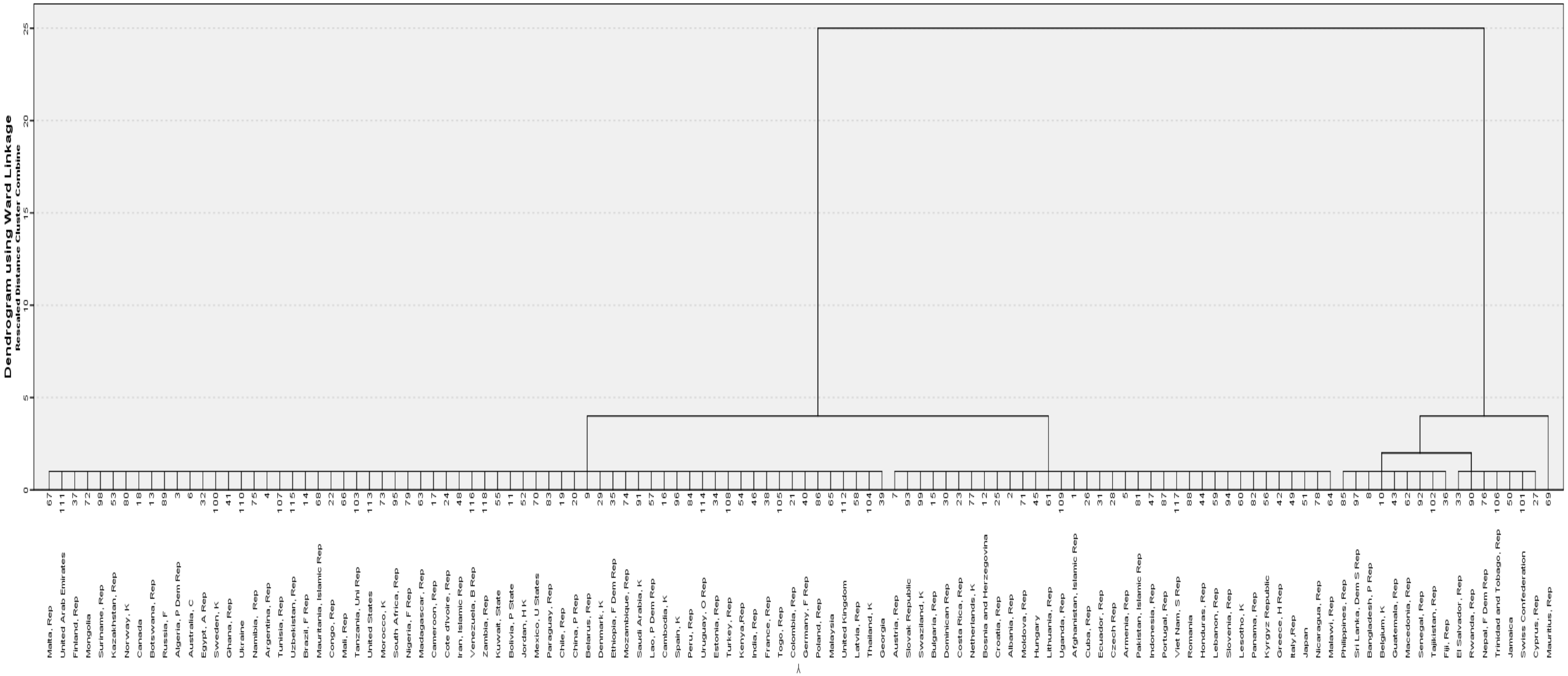

Figure A 2 Dendogram for Clustering of Countries Based on E Component

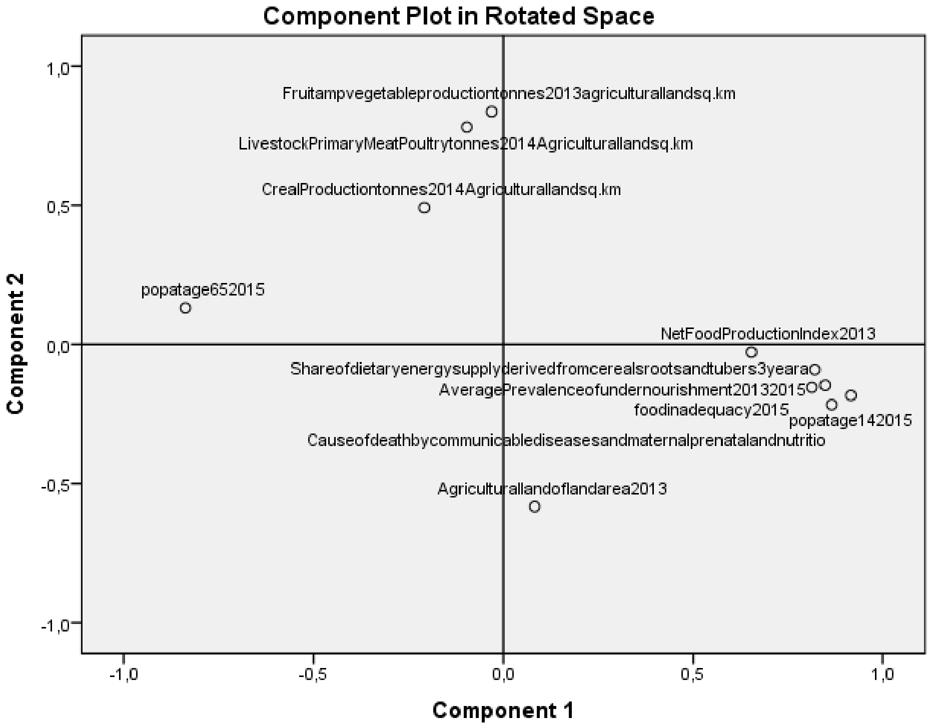

Figure A 3 Component Plot in the Rotated Space for Sensitivity Component

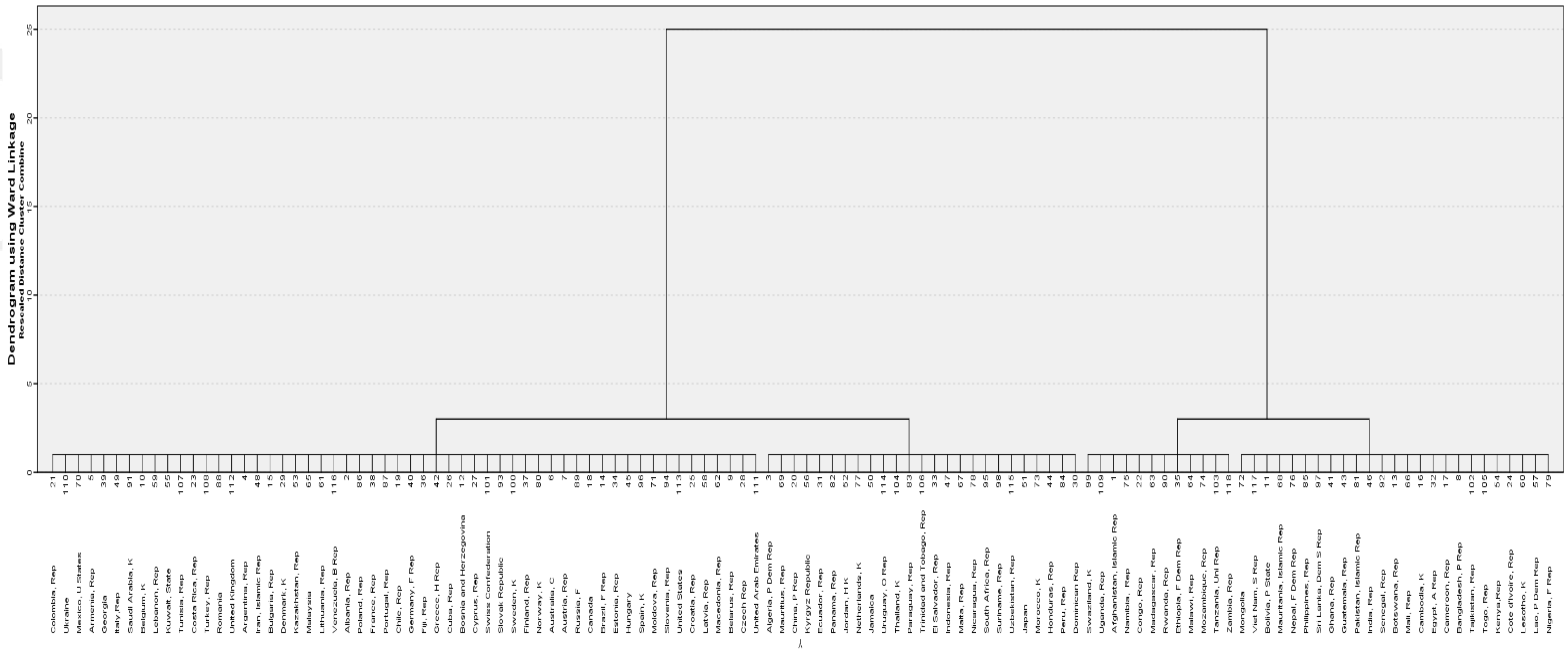

Figure A 4 Dendogram for Clustering of Countries Based on S Component

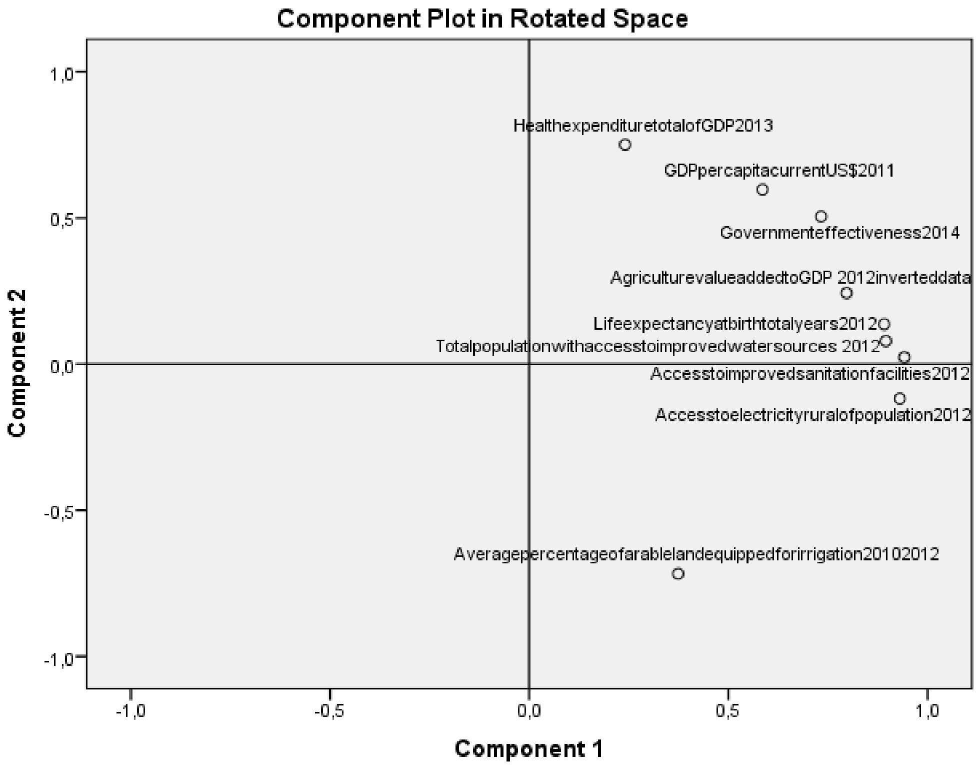

Figure A 5 Component Plot in the Rotated Space for Adaptive Capacity Component

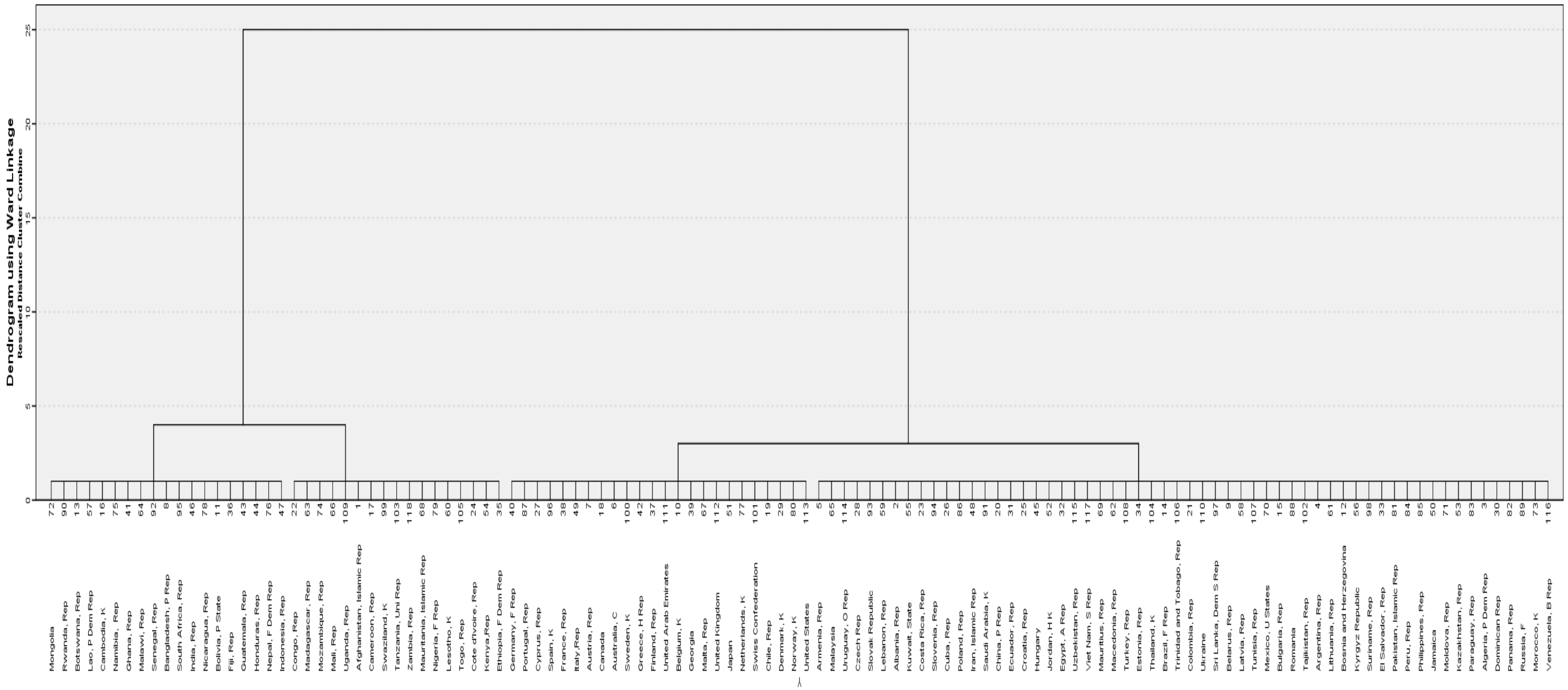

Figure A 6 Dendogram for Clustering of Countries Based on Adaptive Capacity Component

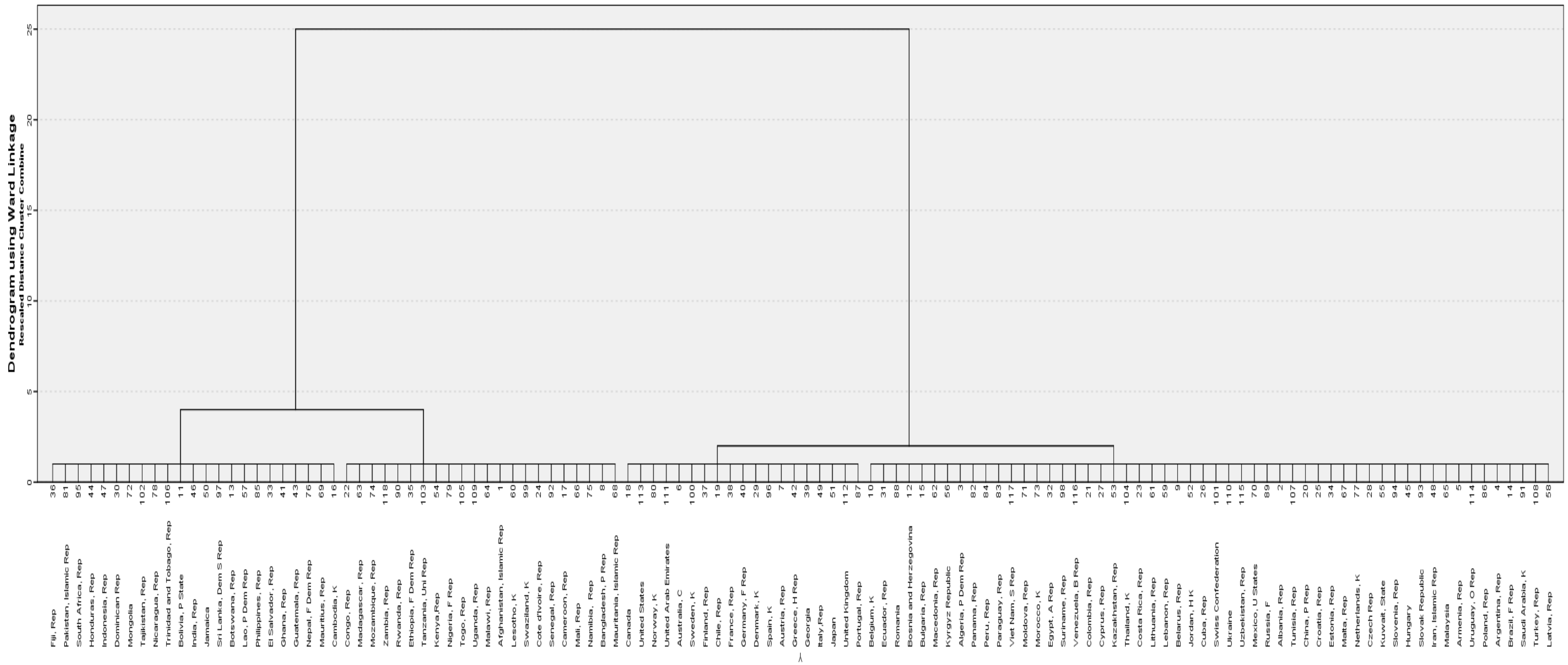

Figure A 7 Dendogram for Clustering of Countries Based on Vulnerability Index

Table A 1 Normalized Exposure Indicator Values

Countries	# of wildfires	# of landslides	# of floods	# of storms	# of droughts	# of extreme temperature events
Afghanistan, Islamic Rep.	0,0049	0,1743	0,1515	0,0036	0,0123	0,0256
Albania, Rep.	0,1055	0	0,4615	0,0266		0,3333
Algeria, P Dem Rep.	0,0027	0,0028	0,0219	0,0005	0,0008	0,0014
Argentina, Rep.	0,0046	0,0049	0,0179	0,0021	0,0014	0,0085
Armenia, Rep.	0	0	0,1538	0,0133	0,0666	0,1111
Australia, C	0,0082	0,0017	0,0078	0,0028	0,0005	0,0026
Austria, Rep	0	0,1666	0,2115	0,04	0	0,2083
Bangladesh, P Rep	0	0,1538	0,5917	0,2738	0,0153	0,4358
Belarus, Rep	0	0	0,0230	0,004	0	0,0833
Belgium, K	0	0	0,6153	0,1733	0	0,6666
Bolivia, P State	0,0117	0,0432	0,0313	0,0007	0,0129	0,0154
Bosnia and Herzegovina	0,0633	0,1333	0,3692	0,016	0,08	0,1666
Botswana, Rep	0	0	0,0188	0,0007	0,0035	0
Brazil, F Rep	0,0011	0,0096	0,0126	0,0004	0,0024	0,0016
Bulgaria, Rep	0,1151	0	0,2657	0,0181	0,0181	0,2727
Cambodia, K	0	0	0,1452	0,0066	0,0444	0
Cameroon, Rep	0	0,0142	0,0425	0	0,0085	0
Canada	0,0041	0	0,004	0,0011	0	0,0007
Chile, Rep	0,0385	0	0,0415	0,0027	0	0,0315
China, P Rep	0,0013	0,0376	0,0309	0,0079	0,0053	0,0042
Colombia, Rep	0,0056	0,1141	0,0679	0,0014	0,0018	0
Congo, Rep	0	0	0,0407	0	0	0
Costa Rica, Rep	0	0,1333	0,6769	0,064	0,08	0
Cote d'Ivoire, Rep	0	0,0208	0,0384	0	0	0
Croatia, Rep	0,2638	0	0,2307	0,0066	0,0333	0,3333
Cuba, Rep	0,0287	0	0,2237	0,0836	0,0727	0

Table A 1- Continued

Countries	# of wildfires	# of landslides	# of floods	# of storms	# of droughts	# of extreme temperature events
Cyprus, Rep	0,3166	0	0	0,08	0,2	1
Czech Rep	0	0	0,25	0,03	0	0,2083
Denmark, K	0	0	0	0,07	0	0
Dominican Rep	0,0633	0	0,6153	0,168	0	0
Ecuador, Rep	0,0253	0,1866	0,1046	0	0,024	0
Egypt, A Rep	0	0	0,0123	0,0012	0	0,0104
El Salvador, Rep	0	0,3333	0,8461	0,26	0,5	0,1666
Estonia, Rep	0	0	0	0,01	0	0,1666
Ethiopia, F Dem	0,0031	0,0133	0,0630	0	0,018	0
Fiji, Rep	0	0	0,6923	0,26	0,1	0
Finland, Rep	0	0	0,0051	0	0	0
France, Rep	0,0287	0,0242	0,0923	0,0247	0,0036	0,0485
Georgia	0	0	0,3076	0,0171	0,0285	0
Germany, F Rep	0	0,019	0,0615	0,0377	0	0,0952
Ghana, Rep	0	0	0,0541	0	0	0
Greece, H Rep	0,1948	0	0,2366	0,0123	0	0,0769
Guatemala, Rep	0,0287	0,4848	0,2377	0,0436	0,0909	0,1212
Honduras, Rep	0,0287	0	0,3076	0,0472	0,1636	0
Hungary	0	0	0,2564	0,0222	0,0222	0,1582
India, Rep	0,0010	0,0606	0,0834	0,0096	0,0033	0,0359
Indonesia, Rep	0,0139	0,151	0,0986	0,0008	0,0022	0
Iran, Islamic Rep	0,001	0,0082	0,0424	0,0017	0,0012	0
Italy,Rep	0,0436	0,1149	0,1485	0,0110	0,0206	0,0919
Jamaica	0	0	0,4615	0,64	0,4	0
Japan	0,0088	0,148	0,0812	0,0855	0	0,0555
Jordan, H K	0	0	0,0170	0,0088	0,0444	0,0370
Kazakhstan, Rep	0,0011	0,0024	0,0062	0,0001	0	0,0037

Table A 1- Continued

Countries	# of wildfires	# of landslides	# of floods	# of storms	# of droughts	# of extreme temperature events
Kenya,Rep	0	0,0468	0,1133	0	0,0315	0
Kuwait, State	0	0	0,0769	0	0	0
Kyrgyz Republic	0	0,2807	0,0324	0,0042	0,0105	0,0351
Lao, P Dem Rep	0	0	0,0936	0,0052	0,0087	0
Latvia, Rep	0	0	0	0,02	0	0,2222
Lebanon, Rep	0,3166	0	0,1538	0,08	0	0
Lesotho, K	0	0	0,1025	0,08	0,2	0
Lithuania, Rep	0	0	0,0512	0,02	0,0333	0,2778
Macedonia, Rep	0,2111	0	0,4615	0,0133	0,0666	0,5555
Madagascar, Rep	0	0	0,0159	0,0255	0,0172	0
Malawi, Rep	0	0	0,4957	0,0133	0,0888	0
Malaysia	0,0383	0,0808	0,1445	0,0072	0,0121	0
Mali, Rep	0	0	0,0239	0	0,0082	0
Malta, Rep	0	0	0	0	0	0
Mauritania, Islamic Rep	0	0	0,0209	0,0003	0,0097	0
Mauritius, Rep	0	0	0,7692	1	1	0
Mexico, U States	0,004	0,0309	0,0301	0,0148	0,0051	0,0189
Moldova, Rep	0	0	0,3589	0,026	0,2	0,2222
Mongolia	0,002	0	0,0049	0,0018	0,0013	0,0021
Morocco, K	0	0	0,0683	0,0035	0,0044	0,0148
Mozambique, Rep	0,0040	0,0084	0,0506	0,0081	0,0202	0
Namibia, Rep	0	0	0,0243	0	0,0122	0
Nepal, F Dem Rep	0,0226	0,8095	0,3076	0,0057	0,0285	0,1428
Netherlands, K	0	0	0,1025	0,16	0	0,5555
Nicaragua, Rep	0,052	0,0555	0,1794	0,0566	0,0833	0
Nigeria, F Rep	0	0,0146	0,0676	0,0017	0	0,0036
Norway, K	0	0	0,0124	0,0043	0	0

Table A 1- Continued

Countries	# of wildfires	# of landslides	# of floods	# of storms	# of droughts	# of extreme temperature events
Pakistan, Islamic Rep	0	0,1385	0,1218	0,0077	0,0026	0,0519
Panama, Rep	0,045	0	0,5934	0,0057	0,0285	0
Paraguay, Rep	0,0079	0	0,0384	0,008	0,03	0,025
Peru, Rep	0,0024	0,0729	0,0348	0,0009	0,0046	0,0234
Philippines, Rep	0,0105	0,4888	0,5333	0,2226	0,02	0
Poland, Rep	0	0	0,0446	0,0154	0	0,1720
Portugal, Rep	0,1759	0	0,1367	0,0311	0,0444	0,1481
Romania	0	0,029	0,2675	0,0156	0,0087	0,2753
Russia, F	0,0042	0,0028	0,0050	0,0004	0,0002	0,0042
Rwanda, Rep	0	1	0,7692	0	0,3	0
Saudi Arabia, K	0,0883	0	0,0100	0	0	0
Senegal, Rep	1	0	0,1214	0,006	0,0315	0
Slovak Republic	0,0633	0	0,3692	0,008	0	0,3333
Slovenia, Rep	0	0	0,2307	0,04	0	0,3333
South Africa, Rep	0,0209	0,0055	0,0317	0,0069	0,0033	0,0055
Spain, K	0,0633	0,0133	0,0461	0,0096	0,004	0,04
Sri Lanka, Dem S Rep	0	0,4444	1	0,0333	0,0666	0
Suriname, Rep	0	0	0,0192	0	0	0
Swaziland, K	0,1583	0	0,2307	0,04	0,2	0
Sweden, K	0,0077	0	0	0,0039	0	0,0081
Swiss Confederation	0	0,6666	0,1923	0,17	0	0,5
Tajikistan, Rep	0	0,5238	0,2747	0,0057	0,0285	0,0714
Tanzania, Uni Rep	0,0035	0,0074	0,0466	0,0022	0,0112	0
Thailand, K	0,0062	0,0392	0,1749	0,0172	0,0313	0,0065
Togo, Rep	0	0	0,3384	0	0	0
Trinidad and Tobago	0	0,6666	0,3076	0,12	0,2	0
Tunisia, Rep	0	0	0,0480	0	0	0

Table A 1- Continued

Countries	# of wildfires	# of landslides	# of floods	# of storms	# of droughts	# of extreme temperature events
Turkey, Rep	0,0164	0,069	0,0519	0,0036	0	0,0259
Uganda, Rep	0	0,1333	0,1384	0,008	0,06	0
Ukraine	0	0	0,0371	0,004	0,0033	0
United Arab Emirates	0	0	0	0	0	0
United Kingdom	0	0	0,1923	0,035	0	0,0972
United States	0,0211	0,0022	0,0181	0,0138	0,0019	0,0065
Uruguay, O Rep	0	0	0,0683	0,0133	0,0111	0,0740
Uzbekistan, Rep	0	0,0155	0,0035	0	0,0046	0
Venezuela, B Rep	0	0,0076	0,0437	0,0013	0,0022	0
Viet Nam, S Rep	0,0102	0,1075	0,3027	0,0838	0,0258	0
Zambia, Rep	0	0,009	0,0332	0	0,0054	0

Table A 2 Normalized sensitivity indicator Values

Countries	Net Food Prod. Index	Livestock Prod.	Creal Production	Fruit & vegetable prod.	Cause of death	% pop at age 65+	% pop at age 14-	Agricultural land	Share of dietary en.	Avr. undern.	food inad.
Afghanistan, Islamic Rep	0,4029	0,0006	0,0291	0,0057	0,6830	0,0540	0,8839	0,7057	0,9464	0,4839	0,6028
Albania, Rep	0,4655	0,0142	0,1418	0,1223	0,0567	0,4468	0,1601	0,5249	0,3036	0,0000	0,0000
Algeria, P Dem Rep	0,6970	0,0056	0,0134	0,0301	0,2006	0,1889	0,4439	0,2068	0,5893	0,0000	0,0277
Argentina, Rep	0,3918	0,0098	0,0611	0,0089	0,1516	0,3873	0,3503	0,6621	0,2143	0,0000	0,0000
Armenia, Rep	0,4761	0,0039	0,0571	0,1068	0,0368	0,3845	0,1567	0,7181	0,3393	0,0300	0,1700
Australia, C	0,4004	0,0023	0,0156	0,0016	0,0337	0,5516	0,1658	0,6267	0,0179	0,0000	0,0000
Austria, Rep	0,2634	0,0334	0,3133	0,0557	0,0184	0,6992	0,0383	0,4623	0,0357	0,0000	0,0000
Bangladesh, P Rep	0,5240	0,0194	1,0000	0,0983	0,4655	0,1520	0,4709	0,8517	1,0000	0,2742	0,4269
Belarus, Rep	0,4501	0,0355	0,1709	0,0278	0,0153	0,5095	0,0911	0,5209	0,2500	0,0000	0,0000
Belgium, K	0,2621	0,2348	0,3954	0,2297	0,0858	0,6778	0,1158	0,5348	0,1071	0,0000	0,0000
Bolivia, P State	0,5252	0,0081	0,0095	0,0042	0,4089	0,2115	0,5561	0,4200	0,5000	0,2673	0,4308
Bosnia and Herzegovina	0,3806	0,0156	0,0826	0,0628	0,0184	0,5675	0,0182	0,5104	0,4643	0,0000	0,0000
Botswana, Rep	0,4819	0,0002	0,0000	0,0001	0,8055	0,0976	0,5433	0,5534	0,4464	0,4562	0,6285
Brazil, F Rep	0,5341	0,0373	0,0597	0,0200	0,1853	0,2659	0,2887	0,4026	0,1786	0,0000	0,0000
Bulgaria, Rep	0,4076	0,0159	0,3153	0,0253	0,0245	0,7496	0,0363	0,5578	0,3393	0,0000	0,0000
Cambodia, K	0,8796	0,0037	0,2812	0,0195	0,5513	0,1183	0,5319	0,3965	0,8571	0,2304	0,3735
Cameroon, Rep	0,7175	0,0060	0,0513	0,0955	0,9051	0,0821	0,8419	0,2464	0,5357	0,1198	0,2292
Canada	0,3684	0,0155	0,1296	0,0052	0,0613	0,5952	0,0883	0,0815	0,0714	0,0000	0,0000
Chile, Rep	0,3837	0,0345	0,0360	0,0607	0,1011	0,3913	0,2069	0,2538	0,3571	0,0000	0,0573

Table A 2 – Continued

Countries	Net Food Prod. Index	Livestock Prod.	Creal Production	Fruit & vegetable prod.	Cause of death	% pop at age 65+	% pop at age 14-	Agricultural land	Share of dietary en.	Avr. undern.	food inad.
China, P Rep	0,4755	0,0297	0,1794	0,0469	0,0597	0,3337	0,1240	0,6657	0,5000	0,1106	0,2292
Colombia, Rep	0,3774	0,0230	0,0135	0,0295	0,1715	0,2341	0,3244	0,4889	0,2500	0,1037	0,2273
Congo, Rep	0,5290	0,0005	0,0001	0,0046	0,9265	0,1000	0,8450	0,3751	0,6607	0,5530	0,6957
Costa Rica, Rep	0,4315	0,0509	0,0209	0,3800	0,0781	0,3079	0,2682	0,4299	0,1786	0,0115	0,1423
Cote d'Ivoire, Rep	0,4490	0,0019	0,0225	0,0164	0,9081	0,0750	0,8405	0,7880	0,7500	0,1935	0,2648
Croatia, Rep	0,2339	0,0196	0,3804	0,0547	0,0000	0,7063	0,0576	0,2788	0,1429	0,0000	0,0000
Cuba, Rep	0,2732	0,0041	0,0258	0,0747	0,0750	0,5091	0,0979	0,7242	0,3571	0,0000	0,0000
Cyprus, Rep	0,1031	0,1804	0,0103	0,2963	0,0429	0,4651	0,1047	0,1381	0,0714	0,0000	0,0000
Czech Rep	0,1880	0,0292	0,3441	0,0107	0,0505	0,6722	0,0619	0,6635	0,1250	0,0000	0,0000
Denmark, K	0,2686	0,0532	0,6073	0,0154	0,0812	0,7071	0,1141	0,7476	0,0893	0,0000	0,0000
Dominican Rep	0,5252	0,0931	0,0527	0,1793	0,2312	0,2187	0,4854	0,5905	0,1429	0,1728	0,3300
Ecuador, Rep	0,3688	0,0368	0,0661	0,1181	0,2511	0,2206	0,4587	0,3645	0,1786	0,1406	0,3024
Egypt, A Rep	0,3943	0,4884	0,9695	0,9208	0,1424	0,1619	0,5478	0,0398	0,7321	0,0000	0,0000
El Salvador, Rep	0,3457	0,0580	0,1043	0,0286	0,1930	0,2790	0,4022	0,9299	0,4464	0,1751	0,3142
Estonia, Rep	0,5115	0,0151	0,2088	0,0101	0,0138	0,6992	0,0917	0,2730	0,2321	0,0000	0,0000
Ethiopia, F Dem R	0,6184	0,0014	0,1073	0,0079	0,8897	0,0929	0,8112	0,4382	0,9286	0,6475	0,7391
Fiji, Rep	0,1375	0,0320	0,0010	0,0091	0,1669	0,1861	0,4508	0,2788	0,4286	0,0000	0,0850
Finland, Rep	0,2187	0,0397	0,3022	0,0146	0,0061	0,7675	0,0988	0,0846	0,1429	0,0000	0,0000
France, Rep	0,2375	0,0488	0,3225	0,0529	0,0720	0,7135	0,1595	0,6380	0,0893	0,0000	0,0000
Georgia	0,1459	0,0032	0,0279	0,0342	0,0291	0,5115	0,1269	0,4438	0,6071	0,0691	0,2233
Germany, F Rep	0,2276	0,0703	0,5150	0,0390	0,0536	0,7976	0,0000	0,5810	0,0714	0,0000	0,0000

Table A 2 – Continued

Countries	Net Food Prod. Index	Livestock Prod.	Creal Production	Fruit & vegetable prod.	Cause of death	% pop at age 65+	% pop at age 14-	Agricultural land	Share of dietary en.	Avr. undern.	food inad.
Ghana, Rep	0,5891	0,0026	0,0289	0,0439	0,7550	0,0893	0,7369	0,8397	0,7500	0,0000	0,0237
Greece, H Rep	0,1533	0,0127	0,0946	0,0924	0,0643	0,8040	0,0721	0,7677	0,1071	0,0000	0,0000
Guatemala, Rep	0,6479	0,0417	0,0854	0,1876	0,5207	0,1472	0,6744	0,4193	0,4107	0,2442	0,3458
Honduras, Rep	0,3932	0,0376	0,0246	0,0822	0,3369	0,1472	0,5365	0,3481	0,4107	0,1682	0,2688
Hungary	0,1605	0,0611	0,5143	0,0578	0,0061	0,6619	0,0483	0,7169	0,1071	0,0000	0,0000
India, Rep	0,5505	0,0106	0,2694	0,1282	0,4058	0,1778	0,4522	0,7372	0,6250	0,2373	0,3834
Indonesia, Rep	0,5405	0,0265	0,2604	0,0522	0,3155	0,1599	0,4209	0,3794	0,8214	0,0599	0,1759
Iran, Islamic Rep	0,3518	0,0343	0,0607	0,0872	0,1271	0,1556	0,3051	0,3411	0,5179	0,0023	0,0988
Italy,Rep	0,2076	0,0729	0,2347	0,2451	0,0368	0,8440	0,0241	0,5618	0,1786	0,0000	0,0000
Jamaica	0,2956	0,1884	0,0005	0,1494	0,1899	0,3175	0,3043	0,4963	0,2857	0,0853	0,2253
Japan	0,2321	0,2576	0,4227	0,3579	0,1807	1,0000	0,0000	0,1461	0,3036	0,0000	0,0000
Jordan, H K	0,5341	0,1497	0,0138	0,2242	0,1807	0,1052	0,6432	0,1394	0,4286	0,0000	0,0000
Kazakhstan, Rep	0,4467	0,0005	0,0126	0,0027	0,0689	0,2230	0,3934	0,9793	0,2679	0,0000	0,0257
Kenya,Rep	0,4267	0,0006	0,0256	0,0215	0,9556	0,0659	0,8246	0,5889	0,5714	0,3802	0,5415
Kuwait, State	0,7957	0,2126	0,0573	0,2714	0,2236	0,0329	0,2685	0,0992	0,3393	0,0000	0,0257
Kyrgyz Republic	0,3432	0,0005	0,0254	0,0141	0,1455	0,1226	0,5263	0,6704	0,5357	0,0230	0,1304
Lao, P Dem Rep	0,6607	0,0087	0,3833	0,0815	0,6325	0,1060	0,5935	0,1175	0,8571	0,3203	0,4842
Latvia, Rep	0,4099	0,0116	0,1968	0,0097	0,0123	0,7234	0,0585	0,3619	0,1607	0,0000	0,0000
Lebanon, Rep	0,2176	0,1041	0,0440	0,3135	0,0720	0,2778	0,3159	0,7824	0,2679	0,0000	0,0870
Lesotho, K	0,3397	0,0006	0,0068	0,0022	0,9602	0,1190	0,6588	0,9033	1,0000	0,1429	0,2569
Lithuania, Rep	0,3817	0,0260	0,2927	0,0150	0,0230	0,7028	0,0468	0,5593	0,2679	0,0000	0,0000

Table A 2 – Continued

Countries	Net Food Prod. Index	Livestock Prod.	Creal Production	Fruit & vegetable prod.	Cause of death	% pop at age 65+	% pop at age 14-	Agricultural land	Share of dietary en.	Avr. undern.	food inad.
Macedonia, Rep	0,3879	0,0011	0,0818	0,1081	0,0031	0,4437	0,1161	0,6062	0,2321	0,0000	0,0000
Madagascar, Rep	0,4093	0,0014	0,0169	0,0045	0,7519	0,0675	0,8189	0,8665	0,9821	0,6406	0,7549
Malawi, Rep	1,0000	0,0031	0,1195	0,0296	0,9755	0,0913	0,9168	0,7467	0,8393	0,3641	0,4585
Malaysia	0,4677	0,1398	0,0572	0,0315	0,2282	0,1885	0,3452	0,2861	0,3750	0,0000	0,0296
Mali, Rep	0,6438	0,0754	0,0276	0,0044	0,9020	0,0548	0,9841	0,4076	0,7857	0,0000	0,0395
Malta, Rep	0,1825	0,3384	0,2941	1,0000	0,0536	0,7187	0,0446	0,3856	0,1964	0,0000	0,0000
Mauritania, Is. R.	0,4034	0,0001	0,0008	0,0000	0,9020	0,0821	0,7709	0,4660	0,4821	0,0184	0,0949
Mauritius, Rep	0,1997	0,4414	0,0030	0,1364	0,1041	0,3341	0,1834	0,5131	0,4464	0,0000	0,1028
Mexico, U States	0,3652	0,0215	0,0562	0,0327	0,1394	0,2115	0,4187	0,6667	0,3571	0,0000	0,0731
Moldova, Rep	0,1531	0,0129	0,1937	0,0631	0,0368	0,3500	0,0815	0,9115	0,3929	0,0000	0,0000
Mongolia	0,5987	0,0000	0,0003	0,0017	0,1531	0,1151	0,4363	0,8880	0,4107	0,3802	0,5336
Morocco, K	0,5099	0,0174	0,0373	0,0345	0,2511	0,1996	0,4076	0,8289	0,6607	0,0000	0,0652
Mozambique, Rep	0,7292	0,0004	0,0052	0,0028	0,9908	0,0877	0,9208	0,7725	0,8929	0,4885	0,5593
Namibia, Rep	0,1762	0,0002	0,0001	0,0002	0,6953	0,0948	0,6764	0,5716	0,5536	0,8594	1,0000
Nepal, F Dem Rep	0,4850	0,0084	0,3835	0,1416	0,4349	0,1750	0,5620	0,3461	0,8036	0,0622	0,1640
Netherlands, K	0,3528	0,4333	0,1518	0,3400	0,0766	0,6782	0,1039	0,6665	0,0536	0,0000	0,0000
Nicaragua, Rep	0,5698	0,0197	0,0281	0,0077	0,2083	0,1567	0,4874	0,5097	0,4821	0,2788	0,3893
Nigeria, F Rep	0,3646	0,0019	0,0599	0,0365	0,9832	0,0635	0,8836	0,9469	0,7321	0,1083	0,1245
Norway, K	0,2828	0,0932	0,2043	0,0220	0,0949	0,6028	0,1450	0,0266	0,1250	0,0000	0,0000
Pakistan, Is. R.	0,1996	0,0202	0,1733	0,0349	0,5651	0,1329	0,6287	0,5707	0,4643	0,3917	0,5020
Panama, Rep	0,3784	0,0521	0,0319	0,0390	0,2420	0,2575	0,4059	0,3658	0,3750	0,1152	0,2431

Table A 2 – Continued

Countries	Net Food Prod. Index	Livestock Prod.	Creal Production	Fruit & vegetable prod.	Cause of death	% pop at age 65+	% pop at age 14-	Agricultural land	Share of dietary en.	Avr. undern.	food inad.
Paraguay, Rep	0,8429	0,0016	0,0374	0,0042	0,2098	0,1937	0,4902	0,6598	0,3750	0,1406	0,2806
Peru, Rep	0,6129	0,0398	0,0334	0,0397	0,3415	0,2258	0,4269	0,2266	0,5893	0,0714	0,1996
Philippines, Rep	0,4163	0,0699	0,3552	0,2031	0,3614	0,1365	0,5419	0,5052	0,6429	0,2051	0,3202
Poland, Rep	0,3065	0,0924	0,3664	0,0739	0,0306	0,5710	0,0593	0,5706	0,3036	0,0000	0,0000
Portugal, Rep	0,2807	0,0744	0,0611	0,1533	0,1286	0,7798	0,0338	0,4811	0,1429	0,0000	0,0000
Romania	0,2350	0,0187	0,2622	0,0512	0,0352	0,6417	0,0755	0,7349	0,3750	0,0000	0,0000
Russia, F	0,4232	0,0129	0,0783	0,0098	0,0704	0,4853	0,1104	0,1559	0,3036	0,0000	0,0000
Rwanda, Rep	0,8163	0,0011	0,0707	0,2659	0,7688	0,0655	0,8002	0,9095	0,4643	0,6382	0,7194
Saudi Arabia, K	0,3100	0,0027	0,0004	0,0025	0,1715	0,0683	0,4462	0,9822	0,4286	0,0000	0,0000
Senegal, Rep	0,4677	0,0058	0,0228	0,0138	0,8545	0,0710	0,8771	0,5616	0,4286	0,1290	0,2451
Slovak Republic	0,1464	0,0274	0,4035	0,0246	0,0582	0,5044	0,0641	0,4853	0,1964	0,0000	0,0000
Slovenia, Rep	0,1165	0,0960	0,2252	0,0633	0,0322	0,6679	0,0545	0,2846	0,2500	0,0000	0,0000
South Africa, Rep	0,4217	0,0125	0,0291	0,0107	0,7213	0,1544	0,4649	0,9726	0,5179	0,0000	0,0059
Spain, K	0,3169	0,0359	0,1246	0,1281	0,0505	0,7004	0,0573	0,6541	0,0179	0,0000	0,0000
Sri Lanka, D. S R.	0,5720	0,0314	0,2187	0,0728	0,1485	0,3238	0,3324	0,5294	0,6071	0,4124	0,4960
Suriname, Rep	0,6732	0,0827	0,5483	0,2166	0,2343	0,2282	0,3951	0,0000	0,3393	0,0760	0,2134
Swaziland, K	0,3455	0,0039	0,0109	0,0131	0,9449	0,0968	0,6951	0,8649	0,6250	0,4954	0,6482
Sweden, K	0,1969	0,0318	0,3132	0,0147	0,0582	0,7460	0,1255	0,0852	0,0714	0,0000	0,0000
Swiss Conf.	0,2564	0,0422	0,1041	0,0579	0,0352	0,6706	0,0545	0,4670	0,0000	0,0000	0,0000
Tajikistan, Rep	0,6829	0,0002	0,0420	0,0579	0,4364	0,0738	0,6239	0,4207	0,6786	0,6682	0,7846
Tanzania, Uni Rep	0,6715	0,0018	0,0441	0,0215	0,8652	0,0817	0,9180	0,5425	0,5893	0,6244	0,6858

Table A 2 – Continued

Countries	Net Food Prod. Index	Livestock Prod.	Creal Production	Fruit & vegetable prod.	Cause of death	% pop at age 65+	% pop at age 14-	Agricultural land	Share of dietary en.	Avr. undern.	food inad.
Thailand, K	0,4704	0,0536	0,2827	0,0763	0,2603	0,3702	0,1377	0,5243	0,4643	0,0668	0,2233
Togo, Rep	0,4400	0,0068	0,0566	0,0061	0,9265	0,0643	0,8339	0,8549	0,8571	0,1820	0,2846
Trinidad Tobago	0,5003	1,0000	0,0190	0,1767	0,1103	0,3282	0,2248	0,1226	0,2321	0,0691	0,1976
Tunisia, Rep	0,3951	0,0168	0,0387	0,0530	0,1440	0,2560	0,2980	0,7784	0,5179	0,0000	0,0000
Turkey, Rep	0,4805	0,0372	0,1404	0,1289	0,0888	0,2540	0,3636	0,6058	0,4107	0,0000	0,0000
Uganda, Rep	0,3458	0,0036	0,0404	0,0841	0,8974	0,0536	1,0000	0,8752	0,3750	0,4677	0,5534
Ukraine	0,5474	0,0229	0,2536	0,0347	0,0567	0,5623	0,0588	0,8673	0,3214	0,0000	0,0000
UAE	0,0000	0,0911	0,0292	0,1451	0,1547	0,0000	0,0307	0,0495	0,3214	0,0000	0,0573
United Kingdom	0,2497	0,0801	0,2346	0,0042	0,0888	0,6595	0,1394	0,8680	0,1429	0,0000	0,0000
United States	0,3514	0,0399	0,1803	0,0171	0,0658	0,5417	0,1729	0,5371	0,0179	0,0000	0,0000
Uruguay, O Rep	0,4826	0,0025	0,0405	0,0057	0,0965	0,5274	0,2427	1,0000	0,3750	0,0000	0,0850
Uzbekistan, Rep	0,7418	0,0010	0,0480	0,0577	0,1884	0,1397	0,4445	0,7653	0,6071	0,0000	0,1028
Venezuela, B Rep	0,4915	0,0476	0,0268	0,0298	0,1485	0,2036	0,4329	0,2938	0,3036	0,0000	0,0000
Viet Nam, S Rep	0,5107	0,0469	0,7631	0,2308	0,2328	0,2222	0,2904	0,4236	0,6429	0,1567	0,2767
Zambia, Rep	0,9063	0,0015	0,0250	0,0025	1,0000	0,0702	0,9381	0,3851	0,8571	1,0000	0,9901

Table A 3 Normalized Adaptive Capacity Indicator Values

Countries	Access to IWS	Access to ISF	GDP	Health exp.	Life exp.	Govern. eff.	Acc. to elec.	A. land eq. for irr.	Agriculture, VA
Afghanistan Rep	0,0565	0,2147	0,0027	0,4049	0,3224	0,0000	0,3061	0,4114	0,4907
Albania, Rep	0,9103	0,9107	0,0407	0,2582	0,8315	0,4789	1,0000	0,5315	0,5488
Algeria, P Dem Rep	0,7057	0,8531	0,0508	0,3080	0,7452	0,2789	1,0000	0,0751	0,8118
Argentina, Rep	0,9727	0,9492	0,1301	0,3505	0,7864	0,4105	0,9567	0,0601	0,8664
Armenia, Rep	0,9942	0,8814	0,0305	0,1681	0,7450	0,4158	1,0000	0,6106	0,5543
Australia, C	1,0000	1,0000	0,6173	0,4932	0,9670	0,9158	1,0000	0,0551	0,9562
Austria, Rep	1,0000	1,0000	0,5066	0,5990	0,9290	0,9105	1,0000	0,0851	0,9747
Bangladesh, P Rep	0,7037	0,5220	0,0048	0,1157	0,6486	0,1474	0,4827	0,6797	0,6483
Belarus, Rep	0,9942	0,9367	0,0594	0,2705	0,6842	0,2947	1,0000	0,0200	0,8012
Belgium, K	1,0000	0,9944	0,4724	0,6090	0,9143	0,8789	1,0000	0,0270	0,9906
Bolivia, P State	0,7758	0,4169	0,0202	0,2703	0,5517	0,2368	0,7194	0,0721	0,7352
Bosnia and Herzegovina	0,9903	0,9412	0,0441	0,5058	0,7949	0,3105	1,0000	0,0020	0,8464
Botswana, Rep	0,9240	0,5751	0,0713	0,2283	0,4484	0,6211	0,2232	0,0060	0,9459
Brazil, F Rep	0,9513	0,7921	0,1266	0,5088	0,7322	0,4263	0,9694	0,0741	0,8964
Bulgaria, Rep	0,9903	0,8418	0,0738	0,3736	0,7422	0,5421	1,0000	0,0300	0,8928
Cambodia, K	0,3918	0,2904	0,0052	0,3664	0,5476	0,1895	0,1714	0,0871	0,2607
Cameroon, Rep	0,4951	0,3808	0,0090	0,2069	0,1775	0,1632	0,1684	0,0040	0,5205
Canada	0,9961	0,9977	0,5162	0,5875	0,9439	0,9526	1,0000	0,0190	0,9751
Chile, Rep	0,9747	0,9864	0,1420	0,3805	0,9380	0,8316	0,9776	0,8549	0,9395
China, P Rep	0,8674	0,6960	0,0521	0,2374	0,7680	0,6368	1,0000	0,6346	0,8070
Colombia, Rep	0,8285	0,7763	0,0686	0,3197	0,7231	0,4526	0,8765	0,6537	0,8642
Congo, Rep	0,5185	0,0350	0,0309	0,1417	0,3701	0,0579	0,0990	0,0030	0,9246
Costa Rica, Rep	0,9513	0,9356	0,0859	0,5219	0,8806	0,6684	0,9867	0,4164	0,8797
Cote d'Ivoire, Rep	0,6335	0,1141	0,0087	0,2463	0,0660	0,1421	0,2755	0,0240	0,5341
Croatia, Rep	0,9883	0,9672	0,1416	0,3522	0,8196	0,7158	1,0000	0,0250	0,9131
Cuba, Rep	0,8850	0,9175	0,0572	0,4519	0,8815	0,4895	0,9526	0,2503	0,9021
Cyprus, Rep	1,0000	1,0000	0,3141	0,3610	0,9017	0,8211	1,0000	0,5225	0,9569
Czech Rep	1,0000	0,9898	0,2125	0,3483	0,8531	0,7895	1,0000	0,0090	0,9527
Denmark, K	1,0000	0,9955	0,6081	0,5718	0,9119	0,9632	1,0000	0,1772	0,9694
Dominican Rep	0,7154	0,8068	0,0545	0,2262	0,7089	0,3158	0,9659	0,3834	0,8754

Table A 3 – Continued

Countries	Access to IWS	Access to ISF	GDP	Health exp.	Life exp.	Govern. eff.	Acc. to elec.	A. land eq. for irr.	Agriculture, VA
Ecuador, Rep	0,7251	0,8056	0,0486	0,3676	0,7766	0,2895	0,9214	1,0000	0,8163
Egypt, A Rep	0,9766	0,9401	0,0246	0,2039	0,6393	0,1316	1,0000	1,0000	0,7033
El Salvador, Rep	0,8363	0,6904	0,0346	0,3285	0,6850	0,4947	0,8541	0,0651	0,7568
Estonia, Rep	0,9903	0,9684	0,1706	0,2477	0,7992	0,8000	1,0000	0,0050	0,9215
Ethiopia, F Dem Rep	0,0565	0,1446	0,0000	0,2040	0,4217	0,3000	0,0567	0,0180	0,0000
Fiji, Rep	0,9142	0,8994	0,0399	0,1424	0,6100	0,3632	0,4434	0,0230	0,7555
Finland, Rep	1,0000	0,9729	0,5032	0,4908	0,9273	0,9947	1,0000	0,0300	0,9496
France, Rep	1,0000	0,9853	0,4336	0,6405	0,9604	0,8842	1,0000	0,1411	0,9688
Georgia	0,9669	0,8655	0,0286	0,4930	0,7310	0,6947	1,0000	1,0000	0,8267
Germany, F Rep	1,0000	0,9910	0,4548	0,6164	0,9335	0,9474	1,0000	0,0541	0,9886
Ghana, Rep	0,7154	0,0328	0,0123	0,2257	0,3548	0,3947	0,3975	0,0060	0,5117
Greece, H Rep	1,0000	0,9887	0,2546	0,5188	0,9216	0,6632	1,0000	0,6116	0,9294
Guatemala, Rep	0,8441	0,5808	0,0280	0,2917	0,6556	0,1789	0,7153	0,2202	0,7711
Honduras, Rep	0,7914	0,7740	0,0196	0,4459	0,6979	0,1368	0,6510	0,0871	0,7003
Hungary	1,0000	0,9774	0,1365	0,4014	0,7656	0,7000	1,0000	0,0380	0,9116
India, Rep	0,8480	0,2938	0,0111	0,1316	0,5444	0,4053	0,6904	0,4254	0,6284
Indonesia, Rep	0,7212	0,5345	0,0328	0,0721	0,5747	0,5105	0,9276	0,2853	0,7201
Iran, Islamic Rep	0,9220	0,8825	0,0750	0,3116	0,7614	0,3263	0,9720	0,5365	0,7958
Italy,Rep	1,0000	0,9944	0,3793	0,4704	0,9697	0,6421	1,0000	0,5676	0,9611
Jamaica	0,8791	0,7932	0,0497	0,2597	0,7132	0,5684	0,8638	0,2072	0,8660
Japan	1,0000	1,0000	0,4575	0,5503	1,0000	0,9737	1,0000	0,5816	0,9815
Jordan, H K	0,9396	0,9842	0,0430	0,3469	0,7258	0,5632	0,9939	0,5095	0,9412
Kazakhstan, Rep	0,8655	0,9718	0,1098	0,1506	0,6255	0,5053	1,0000	0,0871	0,9090
Kenya,Rep	0,2515	0,2045	0,0066	0,1652	0,3494	0,3842	0,0480	0,0180	0,3965
Kuwait, State	0,9805	1,0000	0,4709	0,0601	0,7421	0,4316	0,9271	1,0000	1,0000
Kyrgyz Republic	0,7583	0,9209	0,0077	0,3104	0,6183	0,1158	1,0000	0,8008	0,6044
Lao, P Dem Rep	0,4444	0,6000	0,0094	0,0000	0,4870	0,3421	0,5383	0,2162	0,4181
Latvia, Rep	0,9825	0,8475	0,1340	0,2473	0,7281	0,7632	1,0000	0,0000	0,9290
Lebanon, Rep	0,9805	0,7819	0,0876	0,3437	0,9069	0,3579	1,0000	0,7037	0,8786
Lesotho, K	0,6335	0,2011	0,0088	0,6282	0,0114	0,2737	0,0832	0,0090	0,8824
Lithuania, Rep	0,9181	0,9006	0,1398	0,2817	0,7334	0,7737	1,0000	0,0010	0,9151
Macedonia	0,9883	0,8983	0,0471	0,2954	0,7632	0,5737	1,0000	0,3083	0,7860

Table A 3 – Continue

Countries	**Access to IWS**	**Access to ISF**	**GDP**	**Healt h exp.**	**Life exp.**	**Gover n. eff.**	**Acc. to elec.**	**A. land eq. for irr.**	**Agricu lture, VA**
Madagascar, Rep	0,0000	0,0011	0,0010	0,1492	0,4575	0,0105	0,0622	0,3093	0,4151
Malawi, Rep	0,7018	0,3186	0,0001	0,4204	0,3643	0,1842	0,0000	0,0190	0,3679
Malaysia	0,9591	0,9537	0,1005	0,1355	0,7452	0,8263	1,0000	0,3964	0,7963
Mali, Rep	0,4327	0,1333	0,0032	0,3414	0,2500	0,0684	0,1010	0,0541	0,1200
Malta, Rep	1,0000	1,0000	0,2194	0,4465	0,9248	0,7947	1,0000	0,3864	0,9667
Mauritania, Islamic Rep	0,1559	0,3017	0,0103	0,1186	0,4031	0,0842	0,0240	0,1071	0,5723
Mauritius, Rep	0,9961	0,9209	0,0861	0,1880	0,7420	0,8158	1,0000	0,2513	0,9342
Mexico, U States	0,9045	0,8158	0,0934	0,2817	0,8023	0,5789	0,9714	0,2793	0,9331
Moldova, Rep	0,7641	0,7266	0,0161	0,6497	0,5778	0,3474	1,0000	0,1251	0,7251
Mongolia	0,2924	0,5243	0,0341	0,2666	0,5851	0,3211	0,6924	0,1341	0,7411
Morocco, K	0,6998	0,7243	0,0270	0,2670	0,7202	0,4368	1,0000	0,1842	0,7048
Mozambique, Rep	0,0273	0,0938	0,0017	0,3182	0,1658	0,1737	0,0347	0,0200	0,4090
Namibia, Rep	0,7817	0,2441	0,0517	0,3809	0,4479	0,5526	0,1567	0,0090	0,8248
Nepal, F Dem Rep	0,7836	0,3345	0,0034	0,2658	0,5898	0,1263	0,7098	0,6086	0,2411
Netherlands, K	1,0000	0,9751	0,5307	0,7214	0,9352	0,9789	1,0000	0,4795	0,9696
Nicaragua, Rep	0,7310	0,6249	0,0132	0,4216	0,7436	0,1211	0,4153	0,1301	0,5904
Nigeria, F Rep	0,3275	0,2079	0,0215	0,1255	0,1019	0,0368	0,3306	0,0080	0,5442
Norway, K	1,0000	0,9785	1,0000	0,5023	0,9453	0,9684	1,0000	0,1101	0,9806
Pakistan, Islamic Rep	0,8226	0,5288	0,0087	0,0513	0,4950	0,1526	0,9031	0,9640	0,4917
Panama, Rep	0,8772	0,6994	0,0866	0,3462	0,8281	0,6000	0,7934	0,0591	0,9341
Paraguay, Rep	0,8713	0,8350	0,0362	0,4648	0,6938	0,1000	0,9622	0,0240	0,6269
Peru, Rep	0,7173	0,7028	0,0536	0,2209	0,7369	0,3895	0,7235	0,6186	0,8507
Philippines, Rep	0,8207	0,6814	0,0201	0,1601	0,5581	0,5842	0,8112	0,2893	0,7587
Poland, Rep	0,9610	0,9514	0,1351	0,3098	0,8115	0,7263	1,0000	0,0080	0,9395
Portugal, Rep	0,9981	0,9944	0,2279	0,5113	0,9140	0,7842	1,0000	0,4875	0,9612
Romania	0,9805	0,7548	0,0883	0,2223	0,7421	0,5211	1,0000	0,3504	0,8808
Russia, F	0,9337	0,6859	0,1294	0,3022	0,6436	0,4737	1,0000	0,0350	0,9246
Rwanda, Rep	0,4990	0,5379	0,0025	0,6061	0,4203	0,5263	0,0582	0,0070	0,3052
Saudi Arabia, K	0,9415	1,0000	0,2285	0,0785	0,7338	0,5895	0,9271	0,5115	0,9690
Senegal, Rep	0,5380	0,3910	0,0072	0,1502	0,4926	0,3368	0,2510	0,0330	0,6559
Slovak Republic	1,0000	0,9864	0,1774	0,4124	0,7944	0,7368	1,0000	0,0701	0,9322

Table A 3 – Continued

Countries	Access to IWS	Access to ISF	GDP	Health exp.	Life exp.	Govern. eff.	Acc. to elec.	A. land eq. for irr.	Agriculture, VA
Slovenia, Rep	0,9903	0,9898	0,2457	0,4750	0,9112	0,7789	1,0000	0,0420	0,9609
South Africa, Rep	0,8441	0,6011	0,0771	0,4599	0,2267	0,6263	0,6618	0,1311	0,9568
Spain, K	1,0000	0,9989	0,3141	0,4564	0,9737	0,8368	1,0000	0,3003	0,9558
Sri Lanka, Dem S Rep	0,8694	0,9299	0,0277	0,0837	0,7357	0,5368	0,8567	0,4555	0,7761
Suriname, Rep	0,8986	0,7661	0,0808	0,1722	0,6412	0,4211	1,0000	0,9499	0,8573
Swaziland, K	0,4971	0,5198	0,0373	0,4272	0,0000	0,2579	0,2291	0,2853	0,8500
Sweden, K	1,0000	0,9921	0,5911	0,5114	0,9527	0,9579	1,0000	0,0621	0,9758
Swiss Confederation	1,0000	0,9989	0,8746	0,6275	0,9830	1,0000	1,0000	0,1522	0,9928
Tajikistan, Rep	0,4483	0,9367	0,0048	0,3157	0,5949	0,1579	1,0000	0,8729	0,4487
Tanzania, Uni Rep	0,1306	0,0282	0,0038	0,3527	0,4464	0,2053	0,0163	0,0130	0,3108
Thailand, K	0,9435	0,9232	0,0517	0,1717	0,7359	0,6316	0,9975	0,3994	0,7495
Togo, Rep	0,2417	0,0000	0,0022	0,4393	0,2964	0,0158	0,0699	0,0020	0,1240
Trinidad and Tobago, Rep	0,9045	0,9040	0,1789	0,2304	0,6213	0,6158	0,9898	0,2793	0,9928
Tunisia, Rep	0,9396	0,8904	0,0393	0,3374	0,7184	0,4421	1,0000	0,1612	0,8141
Turkey, Rep	0,9903	0,9288	0,1021	0,2389	0,7629	0,6474	1,0000	0,2492	0,8214
Uganda, Rep	0,5283	0,0791	0,0024	0,5149	0,2567	0,3316	0,0618	0,0010	0,4624
Ukraine	0,9318	0,9525	0,0321	0,3831	0,6461	0,3526	1,0000	0,0661	0,8170
United Arab Emirates	0,9922	0,9718	0,3946	0,0808	0,8216	0,9000	0,9271	1,0000	0,9924
United Kingdom	1,0000	0,9910	0,4058	0,4722	0,9309	0,9263	1,0000	0,0150	0,9928
United States	0,9825	1,0000	0,4932	1,0000	0,8694	0,8947	1,0000	0,1702	0,9798
Uruguay, O Rep	0,9864	0,9537	0,1378	0,4481	0,8111	0,6895	0,9500	0,1351	0,8018
Uzbekistan, Rep	0,7524	1,0000	0,0119	0,2736	0,5608	0,2105	1,0000	0,9730	0,6078
Venezuela, B Rep	0,8616	0,9322	0,1038	0,1076	0,7308	0,0211	1,0000	0,3904	0,8922
Viet Nam, S Rep	0,8791	0,6960	0,0118	0,2628	0,7797	0,4842	0,9761	0,7167	0,5942
Zambia, Rep	0,2788	0,3582	0,0130	0,2019	0,2995	0,3053	0,0383	0,0420	0,7898

Table A 4 Normalized vulnerability component scores

Countries	Normalized E	Normalized S	Norm AC
Afghanistan, Islamic Rep	0,116907016	0,725082396	0,1592892
Albania, Rep	0,22415723	0,178090835	0,8336956
Algeria, P Dem Rep	0,006986065	0,254941519	0,6298382
Argentina, Rep	0,010736859	0,190203381	0,7301696
Armenia, Rep	0,094644521	0,217534234	0,8126325
Australia, C	0,006768636	0,107098604	0,9212932
Austria, Rep	0,187076969	0,110367068	0,9188087
Bangladesh, P Rep	0,426451473	0,651148247	0,4692344
Belarus, Rep	0,030216586	0,139274506	0,6902531
Belgium, K	0,38291721	0,235938742	0,8973466
Bolivia, P State	0,037596663	0,442644496	0,4332384
Bosnia and Herzegovina	0,231659295	0,163380713	0,740114
Botswana, Rep	0,005272722	0,573021779	0,3744618
Brazil, F Rep	0,00837371	0,150334701	0,7023574
Bulgaria, Rep	0,177115918	0,198081364	0,7175341
Cambodia, K	0,048505576	0,561335973	0,2820604
Cameroon, Rep	0,01742504	0,556927164	0,163123
Canada	0,00276073	0,067279872	0,9166803
Chile, Rep	0,02912211	0,157255069	0,9397234
China, P Rep	0,028870288	0,25878256	0,7509943
Colombia, Rep	0,06353767	0,215424542	0,7038421
Congo, Rep	0,00752385	0,735246488	0,0192149
Costa Rica, Rep	0,242752087	0,224633826	0,8548687
Cote d'Ivoire, Rep	0,01587458	0,619912713	0,1340262
Croatia, Rep	0,232515579	0,113711943	0,7874164
Cuba, Rep	0,11678447	0,166418286	0,762927
Cyprus, Rep	0,501071851	0,093272127	0,9091405
Czech Rep	0,119788204	0,13750748	0,8102485
Denmark, K	0,030508307	0,198291463	0,9408559
Dominican Rep	0,205172216	0,350754438	0,6302733
Ecuador, Rep	0,115200721	0,281547741	0,748092
Egypt, A Rep	0,00584008	0,560598393	0,7924873
El Salvador, Rep	0,669164473	0,36877812	0,6132358
Estonia, Rep	0,052777619	0,152627828	0,7787287
Ethiopia, F Dem Rep	0,025766424	0,821946316	0,1479971
Fiji, Rep	0,283429526	0,167334525	0,5163727
Finland, Rep	0,000946521	0,106466121	0,9042063
France, Rep	0,06195265	0,181066943	0,9261992
Georgia	0,076382142	0,220474132	0,8962032

Table A 4 - Continued

Countries	Normalized E	Normalized S	Norm AC
Germany, F Rep	0,063486453	0,159673609	0,9139433
Ghana, Rep	0,010010955	0,50674459	0,2569025
Greece, H Rep	0,127609106	0,168178457	0,9229972
Guatemala, Rep	0,348571104	0,506089497	0,5178149
Honduras, Rep	0,154811912	0,338619166	0,5565196
Hungary	0,11240749	0,147864257	0,7875399
India, Rep	0,057257719	0,496355846	0,4805236
Indonesia, Rep	0,087018368	0,378032922	0,5451992
Iran, Islamic Rep	0,013113272	0,190816041	0,7560912
Italy,Rep	0,128573959	0,21015238	0,9247095
Jamaica	0,533023973	0,277213277	0,657739
Japan	0,133219322	0,321361483	0,9981752
Jordan, H K	0,036546119	0,28274167	0,7893683
Kazakhstan, Rep	0,003670547	0,196902763	0,6664019
Kenya,Rep	0,053937321	0,661286221	0,1260384
Kuwait, State	0,014212032	0,226912799	0,8261376
Kyrgyz Republic	0,140439639	0,263342163	0,7381891
Lao, P Dem Rep	0,023246839	0,597350296	0,3970636
Latvia, Rep	0,07327894	0,130012195	0,7224367
Lebanon, Rep	0,154570831	0,23809742	0,8017277
Lesotho, K	0,138226305	0,626982281	0,1136122
Lithuania, Rep	0,112966709	0,172129514	0,7321255
Macedonia, Rep	0,341473673	0,130599507	0,7816903
Madagascar, Rep	0,021335847	0,81058523	0,0303571
Malawi, Rep	0,134910055	0,818950956	0,2558019
Malaysia	0,080002972	0,202313699	0,8124701
Mali, Rep	0,00788641	0,570374528	0,1719924
Malta, Rep	0	0,379197716	0,8937154
Mauritania, Islamic Rep	0,008130494	0,440909156	0,0669645
Mauritius, Rep	1	0,254368743	0,7735407
Mexico, U States	0,034119894	0,215109561	0,7199258
Moldova, Rep	0,226916286	0,143488066	0,6564334
Mongolia	0,003477516	0,416962401	0,3762675
Morocco, K	0,020354996	0,323159819	0,6402329
Mozambique, Rep	0,026152382	0,832777437	0
Namibia, Rep	0,009654184	0,71914252	0,2822137
Nepal, F Dem Rep	0,459604913	0,448509183	0,5609989
Netherlands, K	0,250084457	0,284898601	1
Nicaragua, Rep	0,131586054	0,380384919	0,4813726
Nigeria, F Rep	0,020490716	0,607294037	0,0749572
Norway, K	0,004189733	0,106372012	0,9605133
Pakistan, Islamic Rep	0,100322308	0,503676706	0,618352

Table A 4 - Continued

Countries	Normalized E	Normalized S	Norm AC
Panama, Rep	0,137231702	0,280980796	0,632303
Paraguay, Rep	0,032798978	0,364364657	0,6623173
Peru, Rep	0,0469917	0,338527781	0,6021292
Philippines, Rep	0,412495237	0,476664796	0,5874829
Poland, Rep	0,064978334	0,177671315	0,7637656
Portugal, Rep	0,151331847	0,183226817	0,9135487
Romania	0,152110445	0,193140407	0,7165049
Russia, F	0,004919286	0,108319752	0,6274427
Rwanda, Rep	0,688953045	0,811720168	0,3761647
Saudi Arabia, K	0,027326691	0,20934259	0,7563731
Senegal, Rep	0,32677528	0,518232022	0,2581317
Slovak Republic	0,186799021	0,103851349	0,8076056
Slovenia, Rep	0,156907993	0,123394752	0,8444206
South Africa, Rep	0,020248253	0,385941477	0,4695739
Spain, K	0,049878974	0,145848629	0,9104233
Sri Lanka, Dem S Rep	0,41419044	0,465995223	0,7075128
Suriname, Rep	0,003553008	0,327700386	0,7440415
Swaziland, K	0,190118824	0,703133929	0,2050183
Sweden, K	0,006291588	0,102730881	0,9203071
Swiss Confederation	0,535025358	0,092293852	0,9884963
Tajikistan, Rep	0,306173235	0,652068811	0,71351
Tanzania, Uni Rep	0,018507389	0,774207535	0,0877295
Thailand, K	0,073250947	0,298898333	0,7804707
Togo, Rep	0,062532939	0,649342344	0,1012892
Trinidad and Tobago, Rep	0,473703234	0,361607978	0,702169
Tunisia, Rep	0,00888252	0,228624136	0,7214319
Turkey, Rep	0,052571808	0,230945436	0,7824565
Uganda, Rep	0,110420286	0,701774204	0,1703178
Ukraine	0,010014537	0,215484822	0,6988552
United Arab Emirates	0	0	0,9033827
United Kingdom	0,079022362	0,19288647	0,8778947
United States	0,019123305	0,120069017	0,970075
Uruguay, O Rep	0,044652871	0,270087813	0,814793
Uzbekistan, Rep	0,009156416	0,328686161	0,7751067
Venezuela, B Rep	0,012825681	0,174509835	0,6464758
Viet Nam, S Rep	0,151508884	0,420952529	0,7760108
Zambia, Rep	0,012206303	1	0,0866256

CURRICULUM VITAE

PERSONAL INFORMATION

Surname, Name	: Yeni, Filiz
Nationality	: Turkish
Date and Place of Birth	: 05.08.1984 /Ankara
Marital Status	: Single
Phone	: +905542712882
e-mail	: filizyeni@gmail.com
website	: filizyeni.com
foreign languages	: English, Spanish

EDUCATION

Degree	Institution	Year of Submission	Year of Graduation
PhD	METU, Earth System Science	2010	-
MS	METU, Biological Sciences	2007	2010
BS	Ankara Uni., Spanish Language and Literature	2014	-
BS	Hacettepe Uni., Biology	2002	2006
High School	Ankara Atatürk Anadolu Lisesi	1998	2002

PROFESSIONAL INTERESTS: Food safety governance, climate change impacts, vulnerability assessment, global institutional mechanisms

HOBBIES: Art jewelry design, outdoor sports.

WORK EXPERIENCE

Year	**Place**	**Enrollment**
2012- 2015	METU, Dept. of Food Eng.	EU Project Assisstant
2013 May-Sept.	National Institute of Microbial Forensics & Food and Agricultural Biosecurity - USA	Visiting Scientist
2009-2010	METU, Dept. of Biological Sciences	Tubitak Scholarship Student
2007-2008	METU, Dept. of Biological Sciences	Tubitak Scholarship Student

PUBLICATIONS:

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