Eco. Env. & Cons. 27 (May Suppl. Issue) : 2021; pp. (S415-S426)
Copyright@ EM International
ISSN 0971–765X

Evidence of Global Warming and Implication for Land and Water Management for Agricultural Development: A case study in Vietnam

Pham Quy Giang[1]*

[1]Faculty of Environment, Ha Long University, Vietnam

(Received 20 September, 2020; Accepted 27 February, 2021)

ABSTRACT

This study was conducted to investigate the existence of global warming at a local scale with a case study of Nghe An, the largest province in Vietnam, and to draw implications for land and water resources management for agricultural development. An ensemble of Global Climate Models simulation with MAGICC/SCENGEN model and a statistical downscaling method were employed for temperature change prediction. The study found that during 40 years from 1971-2010, annual temperature rose by approximately 0.8 °C, meaning that it has risen 0.2 °C per decade. The province is also predicted to face with a severe warming climate in the future, which could warm as much as 3.9 °C by the end of this century. A warmer climate could lead to a number of issues regarding the variability of land and water resources in the province including the negative change of water cycle; the increase in the frequency and intensity of floods and droughts which could destruct the current land and water systems; degradation of land due to soil erosion which causes the loss of fertile soil; water pollution and water quality deterioration due to the transportation of heavy metals, pollutants, pesticides, and chemical fertilizers during heavier rains, etc. It is recommended that countermeasures should be planned in the framework of watershed management, which is the integrated use and management of land, vegetation and water resources while enhancing livelihoods and maintaining ecosystem services in the province.

Key words : *Climate change, Global warming, GCM, Land and water management, Agriculture*

Introduction

Nowadays, climate change has become more and more evident. The Intergovernmental Panel on Climate Change (IPCC) has reported that global mean surface (land and ocean) temperature has risen since the pre-industrial period, and the observed mean land surface air temperature has risen considerably more than the global mean surface (land and ocean) temperature (Figure 1). Globally, nine of the ten warmest years since the instrumental weather record (began in 1880) have occurred since 1990. From a decadal point of view, each of the past three decades has been successively warmer than all the previous decades, and the first decade of the 21st century has been the warmest. More recently, the World Meteorological Organization (WMO) reported that 2014, 2015, and 2016 were successively the warmest years in history (WMO, 2019). The IPCC (2013) has warned that except under the most aggressive mitigation scenario, global mean temperature is expected to rise at least twice as much in the next 100 years as it has during the last 100 years, and ground-level air temperatures are expected to continue to rise more rapidly over land than oceans. It is also noticeable that temperature change is not

---

*Corresponding author's email: phamquygiang@daihochalong.edu.vn

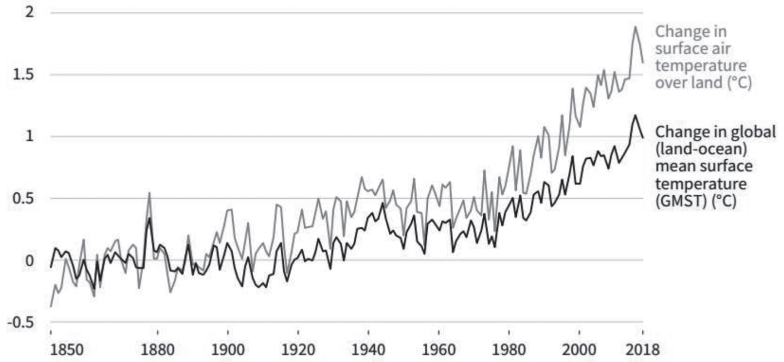


Fig. 1. Observed temperature change relative to 1850-1900 (Source: IPCC, 2019)

uniform across the globe as some regions are projected with larger temperature increases than the global average (Figure 2).

At the 21st Conference of the Parties of the United Nations Framework Convention on Climate Change - UNFCCC (COP21) in Paris, 2015, 195 UNFCCC member nations committed to limit global warming to well below 2.0°C and even to muster strong efforts for limiting the planetary temperature increase to 1.5°C (United Nations, 2016). However, if the world carries on emitting greenhouse gases (GHGs) as the present, and international cooperation to limit climate change fails, a rise of over 4 °C relative to preindustrial times by the end of this century will be unavoidable (ADB, 2017). These would lead to dramatic environmental changes that our world will face.

Vietnam is usually considered as one of the world's most vulnerable countries to the effects of climate change, which threatens the environment, long-term economic growth and sustainable development. In Vietnam, Nghe An is a large province in its central part that is rich of natural resources. The province covers an area of nearly 16,500 square kilometres and has a population of 3,327,791 people (as of 2019), making it the largest province in Vietnam in terms of area and the fourth in terms of population. However, it is desirable to note that the province is located in a very severe climate condition, with a very hot summer and a very cold winter. In the summer, Nghe An is always the hotspot of high temperature over Vietnam, which often rises

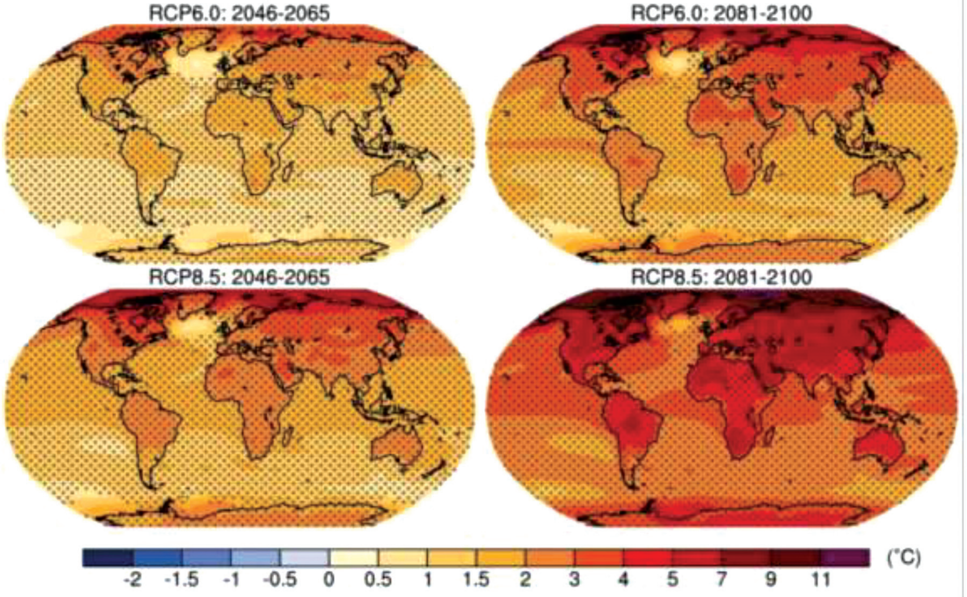


Fig. 2. Projection of temperature rise over the world under RCP6.0 and RCP8.5 scenarios (*Source:* IPCC, 2013)

to over 40 degrees Celsius. The province is also located in a disaster-prone region and is very highly vulnerable to climate change impacts. The main aim of the present study was therefore to investigate the characteristics of temperature over Nghe An Province during recent decades and its future scenarios under the common trend of global warming.

The study addressed the following research questions: Was there a warming trend over Nghe An Province during recent decades and to what extent warming is likely to occur under the effect of increases in GHG emissions? What is the implication of a warmer climate for the management of land and water resources for agricultural development in the study area?

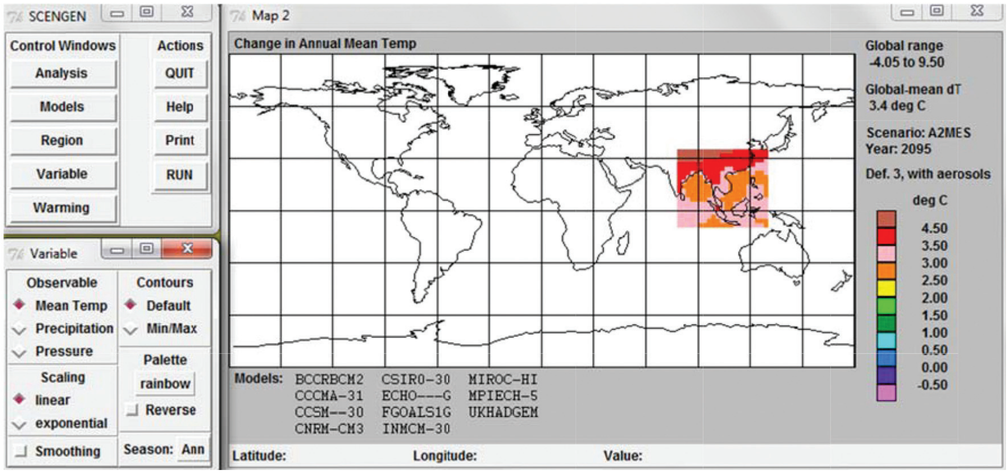
Materials and Method

Climate models and emission scenarios

To achieve the objectives of the study, an ensemble of Global Climate Models (GCMs) simulation method using MAGICC/SCENGEN, which is a coupled gas-cycle/climate model that drives a spatial climate-change scenario generator, was employed. MAGICC produces global and hemispheric-mean temperature output through an upwelling-diffusion, energy-balance climate model (Wigley, 2008). Temperature data produced from MAGICC are then used to run SCENGEN. In SCENGEN, a version of pattern scaling method is used to produce spatial patterns of change from a database of atmosphere/ocean GCM data from the Coupled Model Intercomparison Project Phase 3 (CMIP3)/ AR4 archive (Santer *et al.*, 1990).

The pattern scaling approach is based on the separation of the global-mean and spatial-pattern components of future climate change, and the further separation of the latter into GHG and aerosol components. The above mentioned spatial patterns are "normalized" and expressed as changes per 1 degree Celsius change in global-mean temperature. These normalized GHG and aerosol components are appropriately weighted, added, and scaled up to the global-mean temperature defined by the model (i.e. MAGICC) for a given year, emissions scenario and set of climate model parameter (Wigley, 2008). In MAGICC/SCENGEN, 20 of 24 models of the CMIP3 archive are available with full set of data. These models were developed by 11 developers (countries). This study used 11 out of the 20 models (one model per each developer). The criterion of model selection is that among models of the same developer, the model which is the latest and has the highest spatial resolution will be selected. As a result, the following models were used: BCCR-BCM2.0 (Norway), CCSM3 (USA), CGCM3.1 (Canada), CNRM-CM3 (France), CSIRO-Mk3.0 (Australia), ECHAM5/MPI-OM (Germany), ECHO-G (Germany/Korea), FGOALS-g1.0 (China), INM-CM3.0 (Russia), MIROC3.2 (hires) (Japan), UKMO-HadGEM1 (UK) (Gordon *et al.*, 2002; Yu *et al.*, 2004; Volodin *et al.*, 2004; Hasumi and Emori, 2004; Salas-Mélia, 2005; Jungclaus, 2005; Johns *et al.*, 2006; Collins *et al.*, 2006; PCMDI, 2007). A detailed description of these models was available in Wigley (2008). Figure 3 shows the interface of SCENGEN with variable setup and an example for temperature prediction.

Historical data of climate variables used in this



Observable: ● Mean Temp ○ Precipitation ○ Pressure
Contours: ● Default ○ Min/Max
Scaling: ● linear ○ exponential
☐ Reverse
☐ Smoothing
Season: Ann

Change in Annual Mean Temp
Global range -4.05 to 9.50
Global-mean dT 3.4 deg C
Scenario: A2MES
Year: 2095
Def. 3, with aerosols

Models: BCCRBCM2 CSIRO-30 MIROC-HI CCCMA-31 ECHO---G MPIECH-5 CCSM--30 FGOALS1G UKHADGEM CNRM-CM3 INMCM-30

Fig. 3. Interface of SCENGEN with variable setup and an example for temperature prediction

study was from 1971 to 2010. Projections of temperature change for 2030s, 2060s, and 2090s, which are defined as near, medium and far future, were generated under the scenarios introduced in the Special Report on Emissions Scenarios - SRES of the IPCC. The scenarios used in this study were B1, B2, and A2 which respectively representing low, medium, and high GHG emission levels. Detailed descriptions of the SRES scenarios can be referred to in IPCC (2000) and IPCC (2007).

The study area and data availability

The study focused on Nghe An, which is the largest province of Vietnam with an area of nearly 16,500 square kilometres. About 70% of the area of the province is mountainous with rugged terrain and long slope. The province has a dense river network with the Ca River being the main and largest river with a length of 250 Km within the territory of the province and a mean annual water volume of more than 17 billion m3. In this study, weather data including temperature, precipitation, humidity and evapo-transpiration were collected from the Vietnam Institute of Meteorology, Hydrology and Climate Change (http://www.imh.ac.vn/) and the Hydro-Meteorological Data Center (http://www.hymetdata.gov.vn/). The data were available at five stations, i.e. Con Cuong - Station A (104°54′E, 19°02′N), Do Luong - Station B (105°18′E, 18°54′N), Quy Chau - Station C (105°07′E, 19°34′N), Quy Hop - Station D (105°09′E, 19°19′N), and Tuong Duong - Station E (104°26′E, 19°17′N). A map of Nghe An Province with location of the meteorological stations used in this study is shown in Figure 4.

Downscaling of predicted temperature data

SCENGEN displays its prediction for temperature change on each of the model grid cell. An observation dataset of temperature in the study province was then used to validate model performance. Because the spatial resolution of the grid cell system in SCENGEN is 2.5° × 2.5° (latitude x longitude), which is considerably coarse, a downscaling method was then used to downscale at-grid cell data to at-station data. The downscaling method used in this study was the Statistical Downscaling Model (SDSM) (Wilby *et al.,* 2002), which is a hybrid statistical downscaling method incorporating a weather generator and a multiple linear regression technique. The primary principle of SDSM is to establish the statistical relationship between the predictands and predictors and then indentify required parameters for the weather generator at each grid point. If a certain predictand and predictors have statistically significant relationships, the SDSM can regress the predictands (i.e., surface temperature in this study) based on the predictors provided by GCM outputs using an established equation. To derive relationships between predictor and predictand, artificial neural networks, linear and non-linear regression, canonical correlation and principal components analyses have all been widely

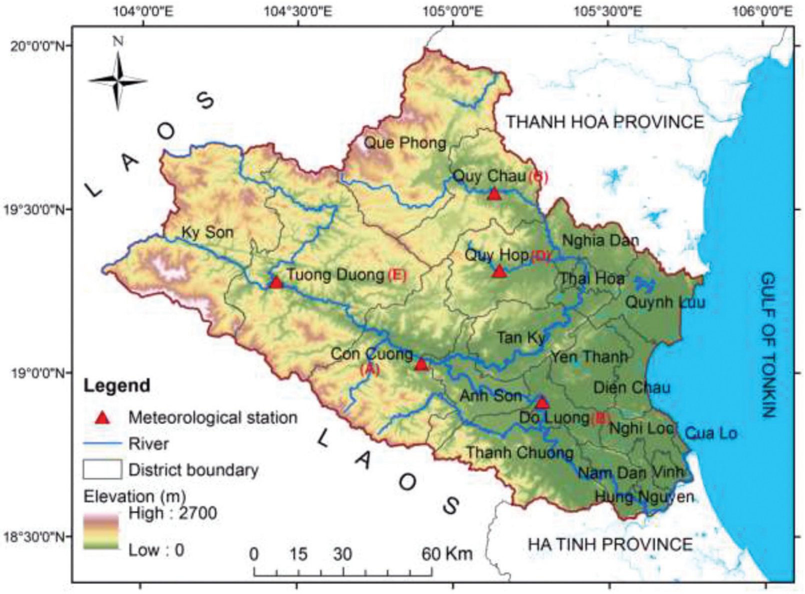


Fig. 4. Map of Nghe An Province with location of meteorological stations

used. In this study, linear regression equations were use. The linear regression equation is $y = ax + b$; where y is temperature observed at a local station, x is temperature predicted for the grid cell at the coordinates of the local station. The advantage of the regression-based downscaling is the relative ease of application, coupled with its use of observable trans-scale relationships. The main disadvantage of this method is that the models often explain only a fraction of the observed climate variability (Wilby *et al.,* 2002).

Analysis of implication for land and water resource management for agricultural development

Based on the warming trend that occurred in the study area in recent decades as well as the prediction for the coming decades, a systematic analysis of the potential change and fluctuation in the natural systems, especially land and hydrological systems was conducted. Finally, implications for land and water resource management for agricultural development were drawn.

Results and Discussion

Characteristics of climate condition of Nghe an Province

Nghe An is located in a tropical monsoon zone characterized by two distinct seasons: Wet season and dry season. The wet season (May to October), is hot and humid due to the south-west monsoon with mean average monthly temperature of the season is 27°C, but the highest temperature can reach 42°C around mid summer (i.e. May to June). The dry season lasts from November to April of the next year, and is cold and dry caused by the north-east monsoon. Mean average monthly temperature in this season is 19°C, with the lowest temperature dropping to nearly 0°C around December and January. Figure 5 shows mean monthly temperature at the five investigated stations during the 40-year observation period (1971–2010) with the Min and Max lines present the lowest and highest temperatures that have occurred in the province in each month during the observation period.

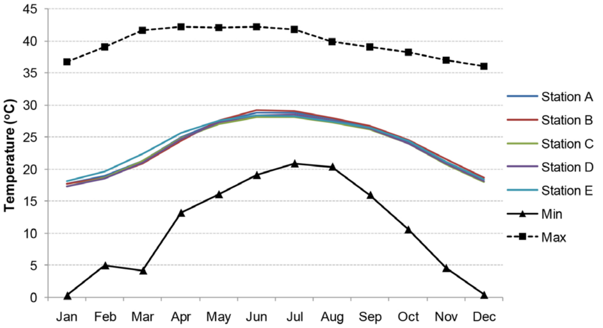


Fig. 5. Mean monthly temperature at observed stations during the 40-year observation period (1971–2010). The Min and Max lines present the lowest and highest temperatures that have occurred in the province in each month during the observation period.

In Nghe An province, precipitation is abundant, but is seasonally and spatially uneven distributed. Data from 40 year observation period shows that annual precipitation in the province may reach 3,000 mm in some wet years. Average annual precipitation at the five observed stations varies from 1,200 mm (at Station E - Tuong Duong) to 1,800 mm (at Station B - Do Luong), with an average of approximately 1,600 mm, of which the wet season accounts for more than 80%. Comparing among months, the months from December to March is very dry with mean monthly precipitation lower than 50 mm, meanwhile the months from August to October receive high amount of precipitation which could reach to 400 mm (Figure 6).

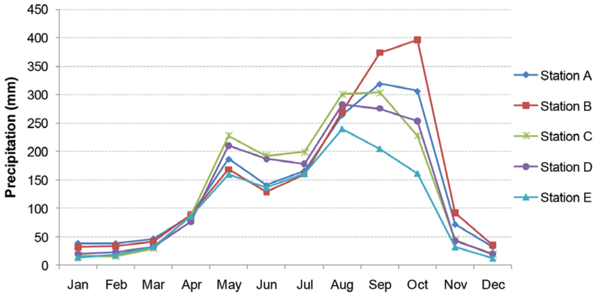


Fig. 6. Mean monthly precipitation at observed stations during the 40-year observation period (1971–2010)

Potential evapotranspiration (PET) in the province is high as a result of high temperature. Figure 7 presents mean monthly PET at the five observed stations during the 40-year observation period. Mean monthly PET values are over 40 mm in all months, and may exceed 120 mm in summer (June and July). Spatially, mean annual PET ranges from 750 to nearly 900mm, with Station C being the lowest and Station E being the highest. Humidity in the province is very high, with monthly values of over 70% in all months during the observation period. Mean annual humidity is around 75–85%.

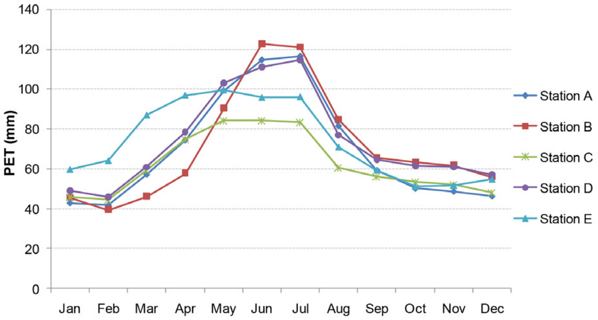


Fig. 7. Mean monthly PET at observed stations during the 40-year observation period (1971–2010)

Trend of temperature during recent decades

Investigation on the evolution of temperature during the past 40 years (1971–2010) in Nghe An Province was conducted. Figure 8 presents time-series data of annual average temperature, annual minimum temperature and annual maximum temperature for each of the 5 observed stations in the province. By establishing a best-fitted trendline, it is possible to observe the changing trend of temperature during the time period. The trend observed for 5 stations is very similar. Although there have been some sharp year-to-year fluctuations during the period (such as large increases in average temperature and maximum temperature in 1998 and in minimum temperature in 2001, and a large decrease in maximum temperature in 2004), the overall trend is up when we look at the whole period. Compared to the beginning of the 1970s, average temperature has increased approximately 0.8 ºC in the end of the first decade of the 21st century, meaning that it has risen 0.2 ºC per decade. This warming rate is higher than that of the country (Vietnam) average temperature, which was reported to be 0.5 ºC during the 50 years from 1960 to 2010 (MONRE, 2012). In comparison with the increase in global average temperature during the same period (about 0.13 ºC per decade according to the Fifth Assessment Report (AR5) of the IPCC (IPCC, 2013), the warming rate observed in Nghe An is also much higher. As such, the studied province is possibly in the area facing severe effects of global warming.

It is noticeable that both minimum and maximum temperatures were found to increase during the observation period, but the increase in minimum temperature was much greater than the increase in maximum temperature. Maximum temperature increased the most at Station A and Station B, with a rate of about 1 oC, and slightly lesser at the other observed stations. Minimum temperature increased gradually until the end of 1990s, when it sharply jumped with a rate of about 3 ºC, and continued to increase from then on. On average, during the observation period, minimum temperature has risen about 6 ºC. A high warming rate in winter may be related to the movement of heat waves and additional effects of GHGs induced global warming. The seasonal asymmetry of warming rate has been reported for global scale (IPCC, 2013), Europe (EEA, 2013), Asia-Pacific (Griffiths, 2005), and Vietnam (MONRE, 2012). This asymmetry leads to a decrease in the seasonal temperature range, indicating a change in the temperature cycle and a possible disturbance of the boundary between seasons.

Projected trend of temperature change in the future

Figure 9 shows increases in mean annual temperature at each station in Nghe An Province. Temperature is predicted to gradually increase throughout the 21st century but with different degree of increment among scenarios. The increase of temperature also slightly varies spatially. At Station A, temperature rises at the highest rate (up to 1.2 ºC, 2.3 ºC and 3.4 ºC respectively in the 2030, 2060s and 2090s under scenrario A2), followed by Station B, and then Station D. Temperature increases least at Station C with 0.9 ºC, 1.8 ºC and 2.7 ºC respectively in the 2030, 2060s and 2090s. The largest disparity in warming tendency among the investigated stations occurs with scenario A2 in 2090s when temperature is predicted to rise by 3.4 ºC at Station A, but by only 2.7 ºC at Station C. Looking at the baseline period, the difference in mean annual temperature between these two stations is 0.3 ºC (23.9 ºC at Station A compared to 23.6 ºC at Station C). As such, although a common warming tendency is predicted, projected climate change is likely to cause a divergence in temperature among local places. On a provincial average, it is predicted to warm as much as 1.0 ºC, 2.0 ºC, and 3.0 ºC by the 2030s, 2060s, and 2090s respectively under the high emission scenario A2.

The characteristic of temperature change in the province is that the three scenarios show similar predictions until the 2030s, with an increase of approximately 1ºC relative to the baseline period. Temperature changes become moderately different in the middle future period (2060s) and the difference enlarges since then with the A2 scenario predicting the largest changes, followed by the B2, and

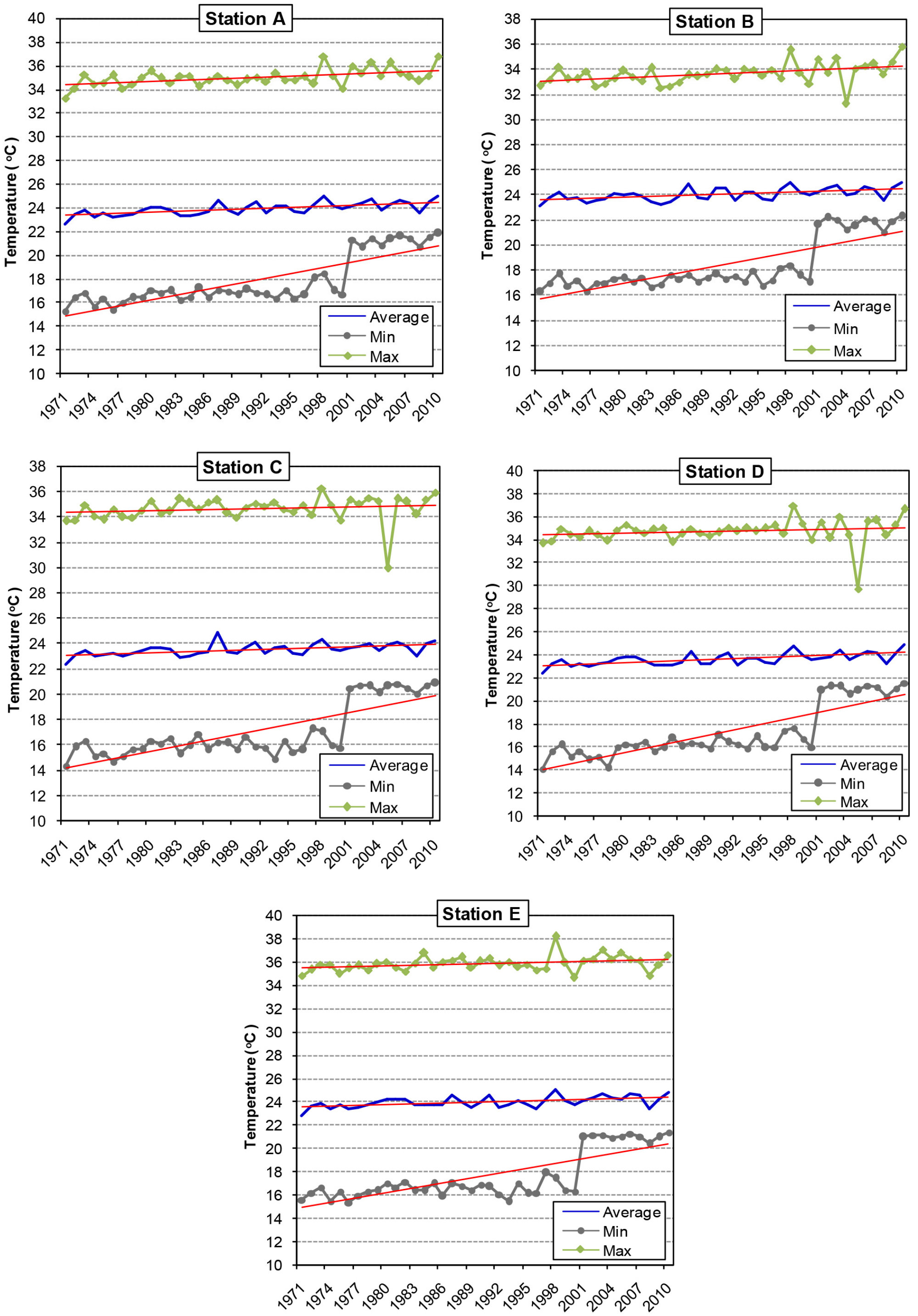


Fig. 8. Historical temperature change during 40-year observation (1971–2010) at 5 investigated stations. The red lines present the best fit linear trend for annual average temperature, annual minimum temperature, and annual maximum temperature.

then the B1 scenario. In the end of 21st century, the differences between scenario A2 and scenarios B2 and B1 are approximately 0.5 ºC and 1.2 ºC, respectively. This is consistent with the characteristics of the emission scenarios of the IPCC's Third and Fourth Assessment Reports (TAR and AR4). This characteristic of temperature change was discussed in Ribalaygua *et al.* (2013) and Pham *et al.* (2014).

From a monthly point of view, results of model prediction show that temperature will increase in all months of the year, but with different warming rates depending on the emission scenario and the month (Figure 10). The smallest warming rates are predicted for August and March, with 2.3 ºC and 2.6 ºC respectively, by the 2090s according to the A2 scenario. In contrast, the months with expected highest warming rate is April, with a rise of 3.9 ºC by the 2090s compared to the baseline average, followed by February (3.6 ºC), June (3.5 ºC), and September (3.5 ºC). Seasonally, temperature is predicted to rise faster in the winter and spring (dry season) than in the summer and autumn (wet season). This characteristic is consistent with the behavior of temperature change during the 40 year observation period, which was previously discussed in section 3.2. A faster rise in temperature in winter and spring may lead to the destruction of the seasonal cycle with shorter winter and spring and leading summer to come earlier than normal.

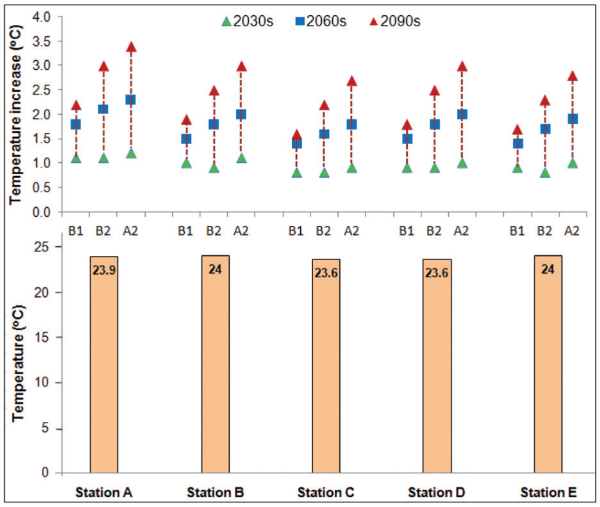


Fig. 9. A combined graph showing average annual temperature of the baseline period and relative change in mean annual temperature under 3 scenarios at 5 stations

Implication for land and water management for agricultural development

This study has found that there was a clear warming trend in the studied province during the 40 year observation period (1971-2010) and it is predicted that a warmer climate is expected in the future. By the end of the 21st century, annual temperature may rise as much as 3.0 ºC while the monthly temperature of the month with the highest warming rate may rise 3.9 ºC under the high emission scenario (A2). These findings imply a number of concerns regarding land and water environment and the management of these natural resources in the province.

As the climate warms, precipitation and potential evapotranspiration are expected to change their intensity, seasonal and spatial patterns, leading to the change in water cycle. With the seasonally uneven distribution of precipitation, droughts and

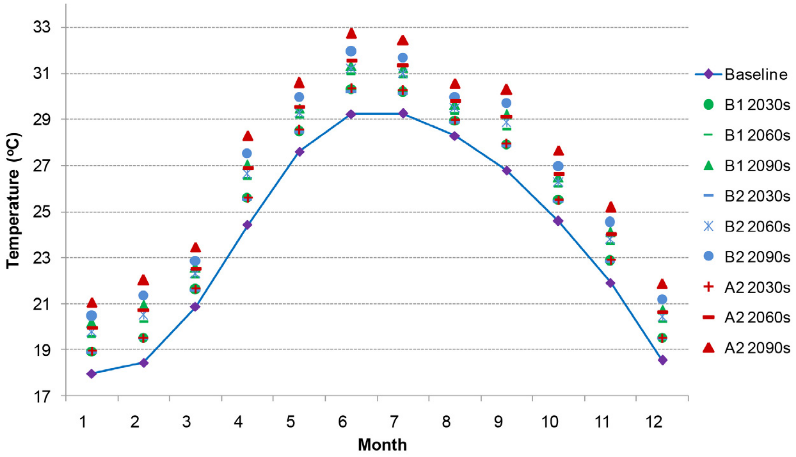


Fig. 10. Change in monthly temperature in the future periods. The graph presents average data for 5 investigated stations in the studied province

floods have occurred very frequently in the province during the past and in recent decades, and this would be exacerbated if the warmer climate causes precipitation to increase in the wet season and to decrease in the dry season. Pham *et al*. (2014) found that in the North Central Vietnam, precipitation in the wet season accounts for more than 80%, meanwhile, the dry season accounts for only the remaining 20% of the annual precipitation. Future climate change could enlarge this difference, which consequently caused water discharge to increase by approximately 10% in the wet season and to decrease by approximately 8% in the dry season. As a result, in the wet season flooding would occur with higher frequency and intensity, causing deeper and longer inundation which leads to an increase by more than 30% in the damage to agricultural production (Pham and Tran, 2018).

Accumulating GHGs and the resulting global warming could have widespread effects on land globally. In fact, most of the impacts of global warming can be viewed as impacts on land. Higher temperatures, increased drought, and more intense thunderstorms will very likely decrease the vegetation cover or shift in vegetation type that protects the land surface, increase erosion and promote the risk of landslides. Arable land, which is suitable for growing crops may be left uncultivated or abandoned completely during periods of episodic drought or converted to open water during periods of above-normal precipitation. Higher temperatures cause the loss of soil moisture, leading to the compaction and hardening of the soil, loss of nutrients such as nitrogen, phosphorus, and potassium, or a decline in the amount of organic matter in the soil. These lead to a significant reduction in land productivity.

Agriculture is land-intensive and climate-sensitive, making it vulnerable to global warming. The effect of global warming on agriculture is complicated as a result of combined effects through land, soil, water, climate condition, and the crops themselves. In general, increased temperatures have been shown to have negative effects on agricultural yields. Figure 11 presents the reduction in yields of some major crops per 1 °C increase in global temperature. The Figure shows the result of simulation using different methods: grid-based simulations (Grid-Sim), point-based simulations (Point-Sim), field-warming experiments (Point-Obs), and statistical regressions at the country level (Regres_A) and the global level (Regres_B) (Zhao et al., 2017). Not only the increase in average temperature makes the effect, but the occurrence of extreme temperature is also even a greater challenge to crops. Extreme heat events can reduce photosynthesis in crops, restrict growth rates of leaves and reduce the growth of the whole crop. Crops therefore can become less resilient to future heat stress as extreme temperature events occur more often. In addition, warming climate conditions and changing rainfall patterns will trigger changes in land- and crop management, such as changes in planting and harvest dates, type of crops, and type of cultivars.

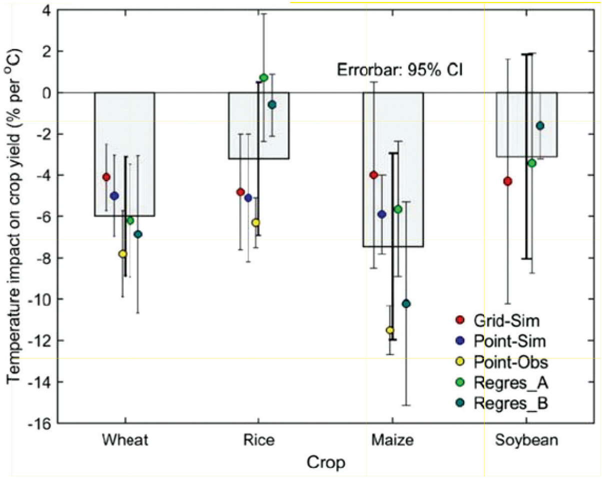


Fig. 11. Loss in crop yield due to increase in temperature (Zhao *et al.,* 2017)

A warmer climate could also cause a change in the regimes of river flow and groundwater discharge and recharge, and reduction of soil moisture, etc. When a warmer climate causes changes in the increase in the intensity of heavy rain, degradation of land due to soil erosion is a foreseen consequence, especially with the area dominated by mountains, hills, and rugged topography like Nghe An Province. Pham *et al.* (2017) found that in the Ca River Basin, which covers Nghe An Province, the average soil erosion rate at the present is over 21 tons per hectare per year, and under climate change impact it would increase by approximately 40% in the wet season. Heavy rain-induced soil erosion causes the loss of fertile soil and degrades inherent soil structure, which consequently leads to a reduction in agricultural crop yield. Soil erosion also leads to decreasing water storage capacity of surface soil and increasing frequency and intensity of floods and droughts. The sediment from the soil erosion process is eventually transported into water bodies, resulting in serious silting in streams, rivers, and reservoirs. Heavy metals, pollutants, pesticides, and chemical fertilizers can also be transported with sediments to water, causing water pollution and water quality deterioration. The resulting high sediment loads can affect the use of river water, especially for water supply to agricultural cultivation.

All of the above discussed potential effects of a warmer climate finally challenge land and water management, especially for agriculture. They are therefore necessary to be taken into account in long-term land and water management in the province. Figure 12 present the interaction between global warming, agriculture, ecosystem and the role of land and water management. In the context of global warming, improving water storage and control systems should be considered as one of the first priorities. Water storage and control play important roles in reducing the risk of floods and droughts. It also has multiple benefits, not only for crop production and diversification but to alleviate the burden of collecting water supply. Water-related interventions should be planned in the broader framework of watershed management, which is the integrated use and management of land, vegetation and water resources through enhancing livelihoods and maintaining the range of ecosystem services. With the characteristics of climate condition and topography of Nghe An province, the framework should emphasize the followings: Land and water conservation measures and afforestation upstream to optimize vegetation cover, water capture and infiltration; soil restoration through integrated soil fertility management, water harvesting and efficient use of water for irrigation, household and livestock use downstream; use of a systems approach to diversify and optimize land use according to the soils, terrain and altitude and to sustain ecosystem services including soil health, water supply and quality, vegetation cover, etc.

Conclusion and Recommendation

Nghe An, with a large land area and a dense river network, can be considered as rich of land and water resources. However, the province is located in a tropical monsoon climate zone with severe climate conditions. The present study found that during the 40 years of observation (1971-2010), average temperature has increased approximately 0.8 °C, meaning that it has risen 0.2 °C per decade. The province is also predicted to face with severe warming climate in the future, which could warm as much as 3.9 °C by the end of this century. A warmer climate could lead to a number of issues regarding the variability of land and water resources in the province including the negative change of water cycle; the increase in the frequency and intensity of floods and droughts which could destruct the current land and

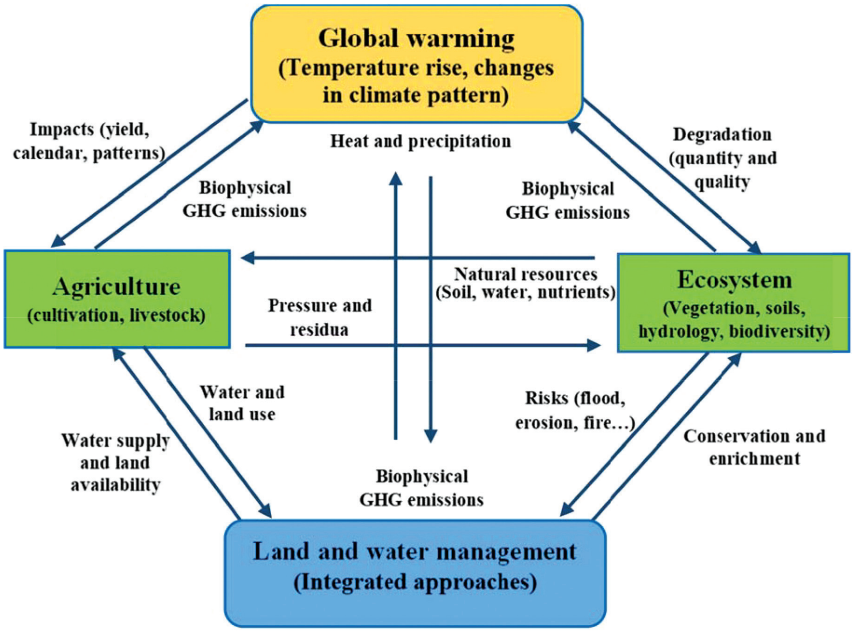


Fig. 12. Land and water management for agriculture in the context of global warming

water system and related infrastructure; degradation of land due to soil erosion which cause the loss of fertile soil, and degrades inherent soil structure; water pollution and water quality deterioration due to the transportation of heavy metals, pollutants, pesticides, and chemical fertilizers during heavy rains, etc. It is therefore recommended that countermeasures should be planned in the long term and broader framework of watershed management, which is the integrated use and management of land, vegetation and water resources while enhancing livelihoods and maintaining the range of ecosystem services in the province.

Acknowledgement

The author is grateful to the Department of Agriculture and Rural Development and Department of Natural Resources and Environment of Nghe An Province, Vietnam Institute of Meteorology, Hydrology and Climate Change, and Hydro-Meteorological Data Center for providing data necessary for this study

References

ADB. 2017. A region at risk: The human dimensions of climate change in Asia and the Pacific. Asian Development Bank, Manila, Philippines.

Collins, W.D., Bitz, C.M., Blackmon, M.L., Bonan, G.B., Bretherton, C.S., Carton, J.A., Chang, P., Doney, S.C., Hack, J.J., Henderson, T.B., Kiehl, J.T., Large, W.G., McKenna, D.S., Santer, B.D. and Smith, R.D. 2006. The Community Climate System Model: CCSM3. Journal of Climate, 19: 2122, CCSM Special Issue.

EEA (European Environment Protection) Global and European temperature (CSI 012/CLIM 001) - Assessment. Available: http://www.eea.europa.eu/data-and-maps/indicators/global-and-european-temperature/global-and-european-temperature-assessment-6. [Accessed: 5 May 2019].

Gordon, H.B., Rotstayn, L.D., McGregor, J.L., Dix, M.R., Kowalczyk, E.A., O'Farrell, S.P., Waterman, L.J., Hirst, A.C., Wilson, S.G., Collier, M.A., Watterson I.G. and Elliott, T.I. 2002. The CSIRO Mk3 Climate System Model [Electronic publication]. Aspendale: CSIRO Atmospheric Research. (CSIRO Atmospheric Research technical paper; no. 60). 130 pp.

Griffiths, G.M., Chambers, L.E. and Haylock, M.R. 2005. Change in mean temperature as a predictor of extreme temperature change in the Asia–Pacific region. *International Journal of Climatology*. 25 : 1301-1330.

Hasumi, H. and Emori, S. 2004. K-1 model developers: K-1 coupled model (MIROC) description, K-1 technical report, 1, Center for Climate System Research, The University of Tokyo, 34pp.

IPCC. (2000). Special Report on Emissions Scenarios: A special report of Working Group III of the Intergovernmental Panel on Climate Change [Naki´enovi, N.; Swart, R. (eds.)]. Cambridge University Press, Cambridge, United Kingdom.

IPCC. 2007. Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC, Geneva, Switzerland, 104 pp.

IPCC. 2013. Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker TF, Qin D, Plattner GK, Tignor M, Allen SK, Boschung J, Nauels A, Xia Y, Bex V and Midgley PM. (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IPCC. 2019. IPCC Special Report on Climate Change and Land. IPCC Secretariat, Geneva, Switzerland.

Johns, T.C., Durman, C.F., Banks, H.T., Roberts, M.J., McLaren, A.J., Ridley, J.K., Senior, C.A., Williams K.D., Jones, A., Rickard, G.J., Cusack, S., Ingram, W.J., Crucifix, M., Sexton, D.M.H., Joshi, M.M., Dong, B.W., Spencer, H., Hill, R.S.R., Gregory, J.M., Keen, A.B., Pardaens, A.K., Lowe, J.A., Bodas-Salcedo, A., Stark, S. and Searl, Y. 2006. The new Hadley Centre climate model HadGEM1: Evaluation of coupled simulations. *Journal of Climate.* 19 (7): 1327-1353.

Jungclaus, J.H., Botzet, M., Haak, H., Keenlyside, N., Luo J.J., Latif, M., Marotzke, J., Mikolajewicz, U. and Roeckner, E. 2005. Ocean circulation and tropical variability in the AOGCM ECHAM5/MPI-OM. *Journal of Climate.* 19 : 3952.

MONRE. 2012. Climate change, sea level rise scenarios for Vietnam. Viet Nam Publishing House of Natural Resources, Environment and Cartography, Hanoi, Vietnam.

Pham, Q.G., Toshiki, K., Sakata, M., Kunikane, S., Tran, Q.V. 2014. Modelling Climate Change Impacts on the Seasonality of Water Resources in the Upper Ca River Watershed in Southeast Asia. The Scientific World Journal. Volume 2014.

Pham, Q.G., Le, T.G. and Toshiki, K. 2017. Spatial and Temporal Responses of Soil Erosion to Climate Change Impacts in a Transnational Watershed in Southeast Asia. *Climate.* 2017, 5 : 22.

Pham, Q.G. and Tran, T.P. 2018. Evaluation of Loss of Rice Production due to Climate Change Reinforced Flood in Vietnam Using Hydrological Model and GIS. *Environment Asia*. 11(3) : 65-78.

Program for Climate Model Diagnosis and Intercomparison (PCMDI). (2007). CMIP3 Climate Model Documentation, References, and Links. Available: https://pcmdi.llnl.gov/ipcc/model_documentation/ipcc_ model_documentation. html. [Accessed: 10 April 2019].

Ribalaygua, J., Pino, M.R., Pórtoles, J., Roldán, E., Gaitán, E., Chinarro, D. and Torres, L. 2013. Climate change scenarios for temperature and precipitation in Aragón (Spain). *Science of the Total Environment.* 463-464 (2013): 1015-1030.

Salas-Mélia, D., Chauvin, F., Déqué, M., Douville, H., Gueremy, J.F., Marquet, P., Planton, S., Royer, J.F. and Tyteca, S. 2005. Description and validation of the CNRM-CM3 global coupled model, CNRM working note 103. Centre National de Recherches Météorologiques, Météo-France, Toulouse, France.

Santer, B.D., Wigley, T.M.L., Schlesinger, M.E., Mitchell, J.F.B. 1990. Developing Climate Scenarios from Equilibrium GCM Results. Max-Planck-Institut für Meteorologie Report No. 47, Hamburg, Germany, 29 pp.

United Nations. 2016. “Paris Agreement”. United Nations Treaty Collection. United Nations, New York City, United States.

Volodin, E.M. and Diansky, N.A. 2004. El-Nino reproduction in coupled general circulation model of atmosphere and ocean. *Russian Meteorology and Hydrology.* 12 : 5-14.

Wigley, T.M.L. 2008. MAGICC/SCENGEN 5.3: User manual version 2. Available: http://www.cgd.ucar.edu/cas/wigley/magicc/UserMan5.3.v2.pdf. [Accessed: 20 February 2019].

Wilby, R.L., Dawson, C.W. and Barrow, E.M. 2002. SDSM - a decision support tool for the assessment of regional climate change impacts. *Environmental Modelling and Software.* 17 (2) : 147–159.

WMO. 2019. WMO confirms past 4 years were warmest on record. Available: https://public.wmo.int/en/media/press-release/wmo-confirms-past-4-years-were-warmes t-record. [Accessed: 10 July 2019].

Yu, Y., Zhang, X. and Guo, Y. 2004. Global coupled ocean-atmosphere general circulation models in LASG/IAP. *Advances in Atmospheric Sciences.* 21 : 444-455.

Zhao, C., Liu, B., Piao, S., Wang, X., Lobell, D.B., Huang, Y., Huang, M., Yao, Y., Bassu, S., Ciais, P., Durand, J.L., Elliott, J., Ewert, F., Janssens, I.A. 2017. Temperature increase reduces global yields. *Proceedings of the National Academy of Sciences*. 114 (35) : 9326-9331.