Journal of Geoscience and Environment Protection, 2015, 3, 111-121
Published Online July 2015 in SciRes. http://www.scirp.org/journal/gep
http://dx.doi.org/10.4236/gep.2015.35013

Perception-Based Analysis (PBA) of Climate Change Impacts on the Forest and Agricultural Ecosystem of Shropshire, United Kingdom

Chukwunonye Ezeah*, Emmah Simbabure

Faculty of Sciences and Engineering, University of Wolverhampton, City Campus-South, Wolverhampton, UK
Email: *C.Ezeah2@wlv.ac.uk

Received 21 May 2015; accepted 25 July 2015; published 28 July 2015

Abstract

Agriculture and forestry are vital sectors providing services, food and other environmental benefits that could be most affected by the impact of climate change (CC). This study analysed the impact of CC on forestry and agriculture in a typical UK rural environment. The study interrogates this complex question using the Perception Based Analysis (PBA) methodological approach. Data analysis utilized chi square test and one-way analysis of variance (Anova) in comparing the impact of climate change and human factors on forest and agricultural ecosystems, (significance level α = 5%), calculated $\rho = 0.36 > 0.05$. This non-significant ρ value suggests that the null hypothesis Ho "climate change is responsible for the changes in forest and agricultural ecosystem in the case study area" could be true.

Keywords

Climate Change Impact, Forest and Agricultural Ecosystem, UK Rural Environment

1. Introduction

The contemporary discourse on climate change CC has often been framed from a complex and rather predictive scientific perspective, based mostly on scenario modelling. Studies indicate that rather than bring greater clarity to the subject, such approach often becomes a vehicle of conflict by promoting the beliefs of different sides to the debate as scientific facts [1]. In addition to this, inherent difficulties associated with many environmental

*Corresponding author.

How to cite this paper: Ezeah, C. and Simbabure, E. (2015) Perception-Based Analysis (PBA) of Climate Change Impacts on the Forest and Agricultural Ecosystem of Shropshire, United Kingdom. *Journal of Geoscience and Environment Protection*, **3**, 111-121. http://dx.doi.org/10.4236/gep.2015.35013

problems also sometimes help to undermine the effectiveness of scientific communication because of the mismatch between "usual modes of understanding" and what is needed to grasp the essence of the problem [2]. Both proponents as well as opponents of climate change have been accused of sometimes deliberately misleading the public [3]. Instead of providing the public with objective basis for making rational decisions on issues, science communication have sometimes been found to be either ineffective or even worsen the situation entirely. In contrast to this trend, this investigation attempts an analysis of the CC phenomenon from a public perception perspective.

There is increasing concern about the variability and impacts of CC on forestry and agricultural production worldwide. These changes have been mostly attributed to anthropogenic influences on the earth's environment [4]. In particular, IPCC Assessment Report 4 [5] supports the view that climate change will have significant impacts on biodiversity, ecosystems and genetic diversity within species as well as on ecological interactions. DEFRA [6] went further to buttress this point, arguing that while on the one hand CC poses added risks to agriculture due to changes in growing seasons, on the other hand it could present positive outcomes to plants that might adapt to anticipated climatic changes. Furthermore, IPCC Working Group II (Adaptation and Vulnerability) estimates that 20% - 30% of plants and animals species evaluated so far in climate change studies were at risk of extinction following temperature spikes projected to occur towards the end of this century. As a result, it has been predicted that some species may migrate northwards or pole wards to where conditions will be more favourable for their existence. Current research indicates that species failing to adapt may be faced with possible extinction or fragmentation. In certain cases, phenological changes are already evident. It therefore follows that, agriculture and forestry are vital sectors providing services, food and other environmental benefits that could be most affected by climate change. This study analyses the impact of CC on a typical UK rural ecosystem with a view to providing empirical evidence that could underpin future CC policies and programmes.

To adequately understand and mitigate CC impacts, evidence based research is required particularly in the agricultural sector. Perception-Based Analysis (PBA) has been used as an alternative to more traditional response-based segmentation [7] [8]. Perception based studies on CC impacts on the forest and agricultural sector are currently under reported; it is therefore imperative for a research like this to use as a case study, a typical rural environment such as Shropshire in middle England. Shropshire borders Wales to the west, Cheshire to the north, Staffordshire to the east, Worcestershire to the south east and Herefordshire to the south. Shropshire is divided into North and South with the Shropshire hills being a major land feature at the south western end (see **Figure 1**). It is estimated that 86% (approximately 128,147 ha) of Shropshire land use is predominantly for agriculture and permanent grasslands [9]. According to DEFRA Statistics [9], in 2008 there were 7026 farm holdings in Shropshire covering 274,549 ha. A total of 7624 individuals, equivalent to 70.2% are engaged in some form of agricultural activities either in full or part time capacity. Shropshire gov. [10] elaborates further

Figure 1. Map of the study area.

that Shropshire's economy depends largely on agriculture, rural industries and tourism. According to Shropshire RCC [11], 43% of Shropshire residents live in rural areas; therefore a disruption in agriculture and forest ecosystems would amount to a significant disruption to their livelihood and economy.

2. Review of Literature

An ecosystem is a dynamic and complex system of plant, animal, and microorganism communities and the non-living environment interacting with each other as a functional unit [12]-[14]. Climate exerts a dominant control over the natural distribution of species within ecosystems. There is increasing evidence from literature that the distribution, composition, structure and function of ecosystems do respond to changes in temperature, precipitation and increased CO_2 levels in the environment [15] [16]. Evidence from fossil records [17] [18] as well as from more recently observed trends [19] [20] also shows that changing climate has a profound influence on species' range, expansion and contraction. Although there is relatively limited evidence of current extinctions caused by climate change, studies suggest that CC could surpass habitat destruction as the greatest global threat to biodiversity over the next few decades [21] in [15]. According to [22], phenology which provides environmental records of leafing, flowering of plants, insect activity (beetles and butterflies) and bird migration are also affected by climate change and global warming [15].

Recent estimates project that agricultural activities are contributing between 12% - 14% of global anthropogenic greenhouse gas emissions, not including emissions arising from land clearing [23]. The precise magnitude of CO_2 emissions from land-use change is still very unclear [5]. In essence, agriculture is highly sensitive to climate change and climatic variations. As a result, there are not only differences among regions, but also differences caused by interannual variability of production and disruption of ecosystem services within a single region [24]. Climate change impacts on agricultural production are also associated with impacts on human well-being and welfare. Changes in agricultural systems, driven by socioeconomic changes, greenhouse gas emissions, agricultural policies and other factors, are also affecting natural and managed ecosystems [25]. From the fore going, CC impacts on ecosystems are far reaching, and could be divided into two main groups: biophysical and socio-economic. This research focuses on the biophysical impacts and their consequential effects such as droughts and floods, which could cause low crop yields and increased incidence of pests and diseases.

Associated with climate change are several factors that affect forest ecosystems, which can act independently or in combination [26]. The changes in timing of seasonal events and migration patterns can result in mismatches between species such as predator prey host relationships hence an imbalance in the ecosystem. A study of 9650 interspecific systems, including pollinators and parasites, suggested that around 6300 species could disappear following the extinction of their associated species [15] [27]. In addition, for many species, the primary impact of climate change may be mediated through effects on synchrony with species' food and habitat requirements. Climate change is also said to have led to phenological shifts in flowering plants and insect pollinators, causing mismatches between plant and pollinator populations that lead to the extinctions of both the plant and the pollinator with expected consequences on the structure of plant–pollinator networks [15] [27].

Bellard *et al*., [15] predicted alarming scenarios of species extinction due to climate change impact in the near future. Indications are that in Europe, with regards to plant diversity, up to 84% plant species could become extinct while as much as 75% of fish depending on river conditions could be wiped out. The study elaborates further that 52 per cent of amphibians could become extinct and 35% of birds could be susceptible to climate change effects and become extinct. These figures are significant and are a cause for concern. Drier conditions and drought could lead to reduced agricultural and timber yields and could also affect woodland conditions [4]. Briner *et al.* [28] and Lindner *et al.* [26] argue that the time spent under drought conditions in most crop growing regions of the world will have drastic consequences on yields and tree growth. While Ray *et al.*, [29], Lindner *et al.*, [26], Briner *et al.*, [28], and the IPCC [4] are unanimous in agreement that drier and warmer summers could heighten the risk of abiotic factors such as wild fires. IPCC [30] goes further to predict increased forest fires as a result of prevailing climatic conditions. This goes to support the position that drought which is exacerbated by climate change could have significant negative impact on forestry and agricultural ecosystem. Fantahun [12] suggests that after wildfires the soil is left without plant cover leaving it susceptible to soil erosion and leaching, rendering it unproductive for agricultural purposes and creating desert like conditions.

[29] [31] and [32] predict that other species may dominate as some species become dormant or extinct. Increased drought stress could equally induce a shift in forest species composition. [31] and [29] elaborated further on what they call "forest disturbances" such as fires, drought, alien species, insects, pathogen outbreaks and

wind storms, agreeing that these will have impacts on species composition and distribution thereby affecting habitat quality and quantity and even cause disruption to ecosystems services [15]. The Fourth Assessment Report, IPCC [5], predicts that some of the species and insects like butterflies for example will begin to appear in hitherto unusual habitats while others will move northwards to where conditions are favourable for their survival. This could have significant effect on those ecosystems as well. The consequence of this is that more drought resistant species are predicted to become dominant component of the forest in the future. Ray *et al.* [29] argue that these new woodlands must be resilient to the impact of climate change. IPCC [30] further argues that there will be increased colonization of alien species in Europe, possibly this could be due to new opportunities in the agricultural sector and woodland environment. Ray *et al.* [29] suggest further that in the future, woodlands could be ideal for carbon sequestration, apart from providing wood fiber for timber products.

Climatic change is also predicted to impact on biotic factors such as frequency and consequences of pests and disease outbreaks [26] [31]. Ray *et al.* [29] emphasized on the influence of warmer weather and warmer winter, especially that they could cause a diversity of pests and pathogens. IPCC [5] supports this analogy and predicts that pests especially beetles outbreak will have fatal effects on pine trees population; Dale *et al.* [31] also agreed with this position while reporting that in their research they found evidence that pine bark beetle disease destroys forests. It has been noted that weeds and pests thrive under warmer and increased temperatures, wetter climates and enhanced CO_2 levels. Under this scenario, the wider range of weeds and pests are likely to move northwards and different weeds will occupy their space. This could cause increase in pollution as more pesticides and fungicides will be required to control the weeds and pests which will in turn harm water courses.

Bellard *et al.* [15] stressed the positive aspects of climate change, particularly with regard to increased temperatures and increased CO_2, pointing out that they could result in an accelerated biomass production. Increased precipitation could also benefit some plants and communities depending on how they will respond to extreme rainfall [15]. In a separate study Bellamy and Hulme [33] discussed people's perceptions and touched on the emotional issues as well as cultural perceptions pertaining to climate change. Bellamy and Hulme [33] used terms such as "catastrophic" and "beyond the tipping point", to describe events and scenarios around climate change. Such terms evoke fear in people regarding climate change. Without doubt, there will be noticeable changes both in woodland as well as in forest ecosystems [31], though the extent of such changes may vary from place to place. Invariably, woodland recreation may be boosted as people seek shelter from the increased temperatures.

3. Methodology

This research utilizes a multi-pronged PBA methodological approach incorporating, desk top study, participant observation, key informant interview and questionnaire survey. At the desktop study stage, mostly secondary data were collected; in the course of reviewing of current literature on the subject. Thereafter the study area was divided into four zones, Shrewsbury, Telford, Shifnal and Bridgnorth. Following the desktop survey, the authors undertook a number of visits to the site to observe the case study area and interview selected key informants from Shropshire Council, National Farmers Union, and Shrewsbury Botanical Gardens. Finally, a survey questionnaire consisting of 13 questions was designed. The survey focused on ascertaining respondents' perception on the relative impact of climate change on forest and agricultural ecosystems in the case study area. To reduce the time and cost of questionnaire administration, an online format of the questionnaire was adapted using the Survey Monkey sampling software. The online questionnaires were thereafter emailed to 250 individuals who live and work in Bridgnorth, Telford, Shrewsbury and Shifnal during the summer of 2014, using the stratified random sampling approach. **Figure 2** is an indicative map with questionnaire sampling and interview areas inset. A total of 100 responses were returned equivalent to about 40% response rate. This rate is well above the norm (20% - 30%) for postal questionnaires [34]-[36]. Most of the data collected were ordinal in nature, although there were some nominal data as well. Data analysis was carried out using the Statistical Programme for Social Sciences (SPSS) for Windows 17.0.

Statistical Data Analysis

Define Statistical analysis utilized chi square test and analysis of variance (ANOVA) to analyse some of the numerical data. A null hypothesis was propounded that "climate change is responsible for the changes in forest and agricultural ecosystem in the case study area". Questions 3, 5, 6, 7 and 11 from the questionnaire were

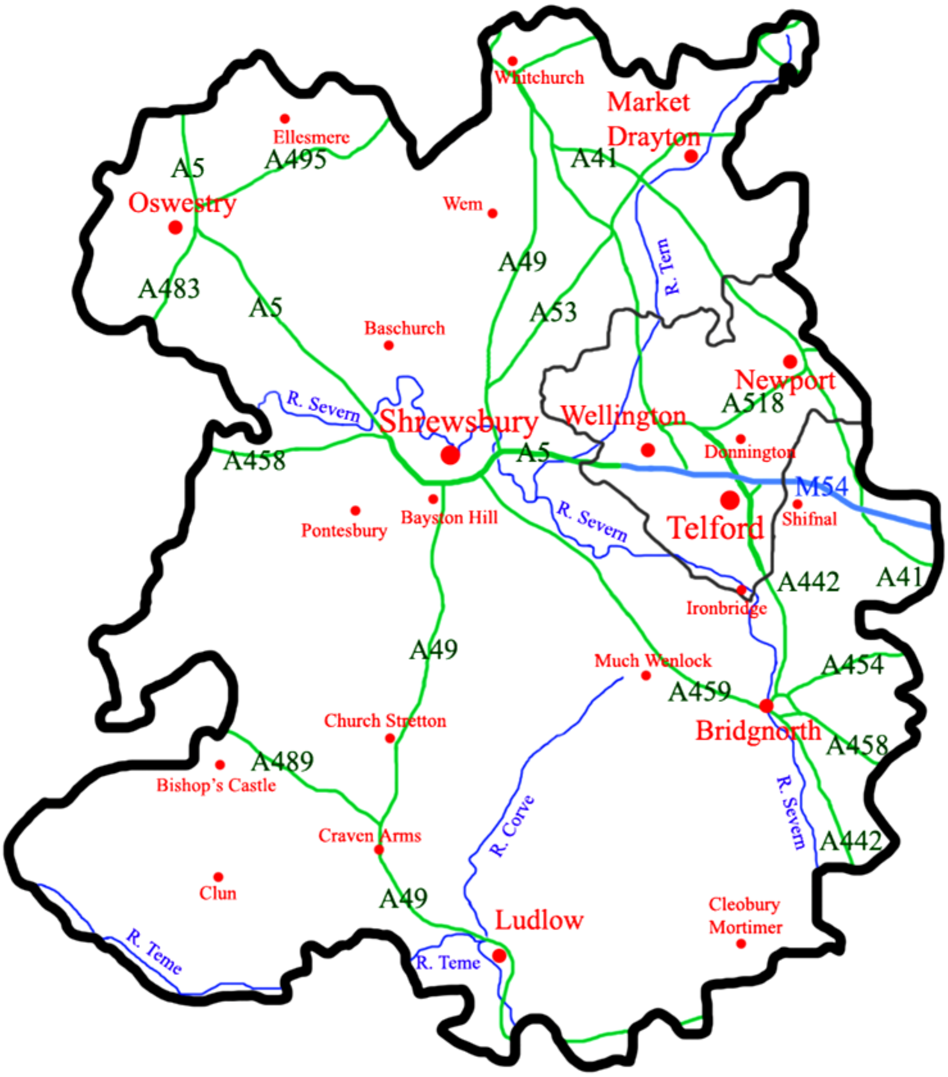

Figure 2. Key interview areas [★] andpaper based questionnaire distribution areas [★].

subjected to chi square test, represented by the formula:

$$X^2 = \sum \frac{(\text{observed} - \text{expected})^2}{\text{expected}} \quad (1)$$

where:

o = Observed Frequency in each category,

e = Expected Frequency in the corresponding category,

d_o = degree of freedom (n − 1),

n = 100,

X^2 = Chi Square.

In addition, we used one-way comparison analyses of variance (Anova) in predicting any variations in CC indicators such as rainfall and temperature over a defined period.

4. Results

Table 1 is an overview of respondents' occupation groups. Table 2 is an outline of respondents' perception on the causes and impacts of CC. One way analyses of variance (Anova) was used in comparing climate change

Table 1. Respondents' occupation group.

Response	Occupation Group				
	C	M	T	O	Total
Agree	14	1	2	12	**29**
Neutral	6	3	4	5	**18**
Disagree	6	10	12	16	**44**
Total	**26**	**14**	**18**	**33**	**91**

C = Carers, M = Managers, T = Technical, O = Others.

Table 2. Causes and impact of climate change.

	Percentage of Respondents						
Human factors are causing climate change	3.30	3.30	24.10	52.70	16.40	100	3.76
Climate change has had significant impact on businesses in Shropshire	3.26	5.43	52.17	35.87	3.26	100	3.3
	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Total	Average rating

and human factors. The significance level $\alpha = 5\%$, calculated $\rho = 0.36 > 0.05$. **Table 3** represents results for test of homogeneitythat the population variances are equal. Based on Anova results, the null hypothesis H_o that "climate change is responsible for changes in forest and agricultural ecosystem in the case study area" is accepted.

5. Discussion

Primary data were collected using the stratified random sampling technique across four districts of Shropshire and Telford councils: Bridgnorth, Telford, Shrewsbury and Shifnal. Bellamy and Hulme [33] have previously studied public perceptions on CC and noted that the subject was often associated with a culture of fear, best reflected by some of the words used to describe scenarios and events surrounding climate change, such as "catastrophic" and "point of no return". This investigation was designed to avoid such elements of fear and subjectivity in analyzing people's perception of climate change. Like Bellamy and Hulme [33], the research employed both qualitative and quantitative approaches but differed slightly from earlier PBA studies because it did not touch on emotions and the myth or the abruptness of climate change.

5.1. Relative Impact of Climate Change on Ecosystems

In response to questions 5 and 6 designed to find out whether "Climate change is causing floods, rainfall variability and warmer temperatures" 63.33% of respondents agreed while 13.53% strongly agreed (see **Figure 3** and **Figure 4**). It is possible that there could be other factors responsible for the perceived impacts (see **Table 2**), for instance respondents could have been influenced by recent memories of the floods that inundated Shropshire's Abbey Foregate road and other places in 2014. Elaborating further on this theme, National Farmers Union (NFU) in Cork [37] suggested that Shropshire "has periodically been affected by floods that threaten livestock; in particular, farmers around River Severn and Shrewsbury have been the most impacted with entire farmlands sometimes underwater, this was the case following late arrival of spring in 2013. While Blessington and Shields [38] were of the opinion that it is too early to conclude that the changes in the ecosystems were solely due to CC, IPCC [5] suggests that CC could cause significant changes in ecosystem composition if increases in global average temperature exceed 1.5˚C - 2.5˚C in which case, they predict that as much as 20 - 30 percent of species will be at risk of extinction.

Drier conditions and drought are other key impacts of CC that could lead to reduced agricultural and timber yields and also affect woodland conditions [4]. Briner *et al.* [28] and Lindner *et al.* [26] argue that the time spent under drought conditions in most crop growing regions of the world will have drastic consequences on yields

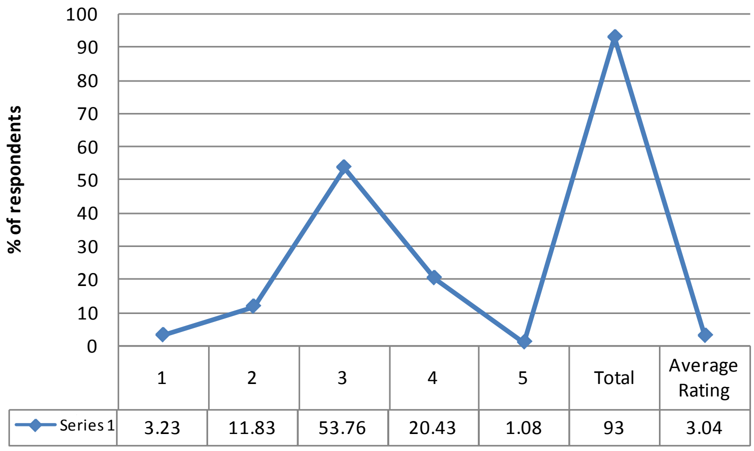

Figure 3. On a sliding scale where 1 is minimal and 5 is maximum impact, do you agree that there have been changes in the forest and agricultural ecosystems in rural Shropshire.

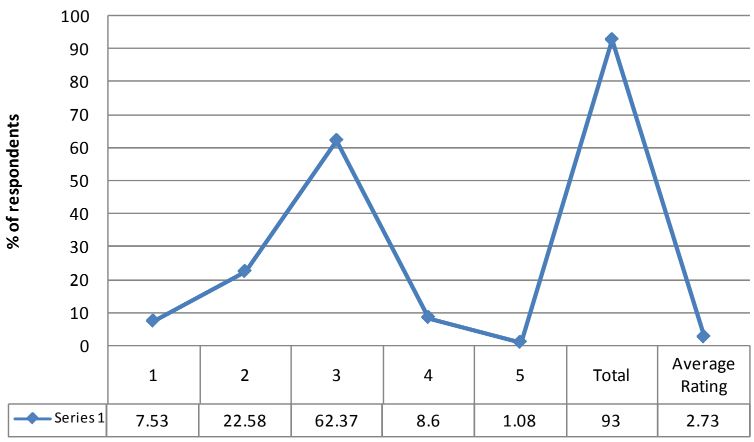

Figure 4. On a sliding scale where 1 is minimal and 5 is maximum impact, do you agree that the changes in the forest and agricultural ecosystems in rural Shropshire can be ascribed mainly to climate change.

Table 3. Test of Homogeneity of variances.

	Levene Statistic	df 1	df 2	Sig.
Climate change	0.653	5	94	0.660
Human factors	4.733	5	93	0.001

and tree growth. While Ray *et al.* [29], Lindner *et al*., [26], Briner *et al.* [28], and the IPCC [4] suggest that drier and warmer summers will heighten the risk of abiotic factors such as wild fire; IPCC [30] and Herbeck [39] on the other hand predict increased burnt forest areas in the near future. There appears to be a convergence of opinion that drought, which evidence indicates is exacerbated by climate change, will continue to have negative impacts on forest and agricultural ecosystem, particularly in rural environments. Fantahun [12] went further to point out that after wildfire incidents, the soil is often left bare and becomes more susceptible to soil erosion and leaching. This renders areas of farmlands unproductive for agricultural purposes and creates desert like conditions.

Interview results from this investigation provided particular insight on the fate of a number of plant species such as sycamore tree in rural Shropshire. Most respondents agreed with Blessington and Shield [38] on the reason why sycamore trees were doing well in Shropshire and pointed out that Sycamore trees were much more adaptable than other plant species. This is possibly due to their capacity to tolerate significant variations in weather conditions, for instance soil salinity and acidity (pH). It has also been suggested that the sycamore tree is capable of thriving under increased temperatures and flooding [5] as well as heavy precipitation [40] [41]. FAO [42] agreed with the notion that CC could provide opportunities for certain plants species to thrive due to high CO_2 levels and lengthening growing season during the year.

5.2. Livestock

Predictably, it is not only plant species that are impacted on by CC but also livestock. It has been reported that CC has both direct and indirect impact on livestock productivity through changes on the availability of fodder and pastures [43]. IPCC [30] and National Farmers Union [37] elaborated further on the likely impact of floods on livestock in rural areas such as Shropshire, particularly through disease infestation on pastoral herds. A recent global assessment found out that climate change could alter livestock numbers at the "local breed" level [44]. Herbeck [39] reported that in most regions of the world local breeds make up two thirds of all breeds, equivalent to 5067 out of a total of 7600 breeds recorded by FAO. FAO [44] predicts the possible extinction of local livestock breeds in the near future while pointing out that around 1500 breeds have already become extinct in the last 15 years. Though results from the this research could not validate findings in the FAO reports, IPCC [30] however agrees that beef production is likely to decline and sheep and goat production increase in the case study area, possibly as a result of changes in growing conditions. Large-scale commercial beef cattle farmers are most vulnerable to climate change, particularly since they are less likely to have diversified. Shropshire has good numbers of sheep but this research could not provide evidence to indicate a decline of beef cattle in the area as a result of CC impact.

5.3. Fish

A separate species study cited by Bellard *et al.* [15] predicted alarming scenarios of species extinction due to climate change impact. In Europe in particular, estimates indicate that up to 75% of fish population could become extinct, depending on river habitat conditions and severity of CC impact. The study also indicates that 52% amphibians and 35% of birds could be susceptible to climate change adverse impacts and become extinct. These figures are significant and are a cause for concern. This research did not generate any evidence to back the position of literature on species extinction but public opinion seems to point to the fact that species are declining in rural Shropshire [38]. It has been further argued that CC impacts, such as warming of oceans, rivers and lakes and changes in precipitation, water salinity and ocean acidity as well as the increases in extreme weather events, will increase uncertainties in the supply of fish from capture fisheries and aquaculture [44]. Severe weather events could also upset the balance of supply [30]. Results from this investigation agree that CC will impact on fish numbers, production and jobs. On the other hand, FAO [42] agrees that fish numbers will be affected but argue that it would be due to water scarcity as there will be competition for water usage.

5.4. Infrastructure

Cork [37] reported that farm sheds where broken down when Shropshire was hit by extreme weather in 2013. This is similar to the situation described by [5] and [30] where it was reported that extreme weather events caused by CC will affect food security by damaging infrastructure for food supply. Post-harvest aspects of agriculture i.e. on-farm storage and commercial activities, handling and transport, will also be affected by changes in temperature, rainfall, humidity, and by other weather dependant factors. As a result, a significant numbers of adaptation projects have been reported by literature. The IPCC [5] and Herbeck [39] are of the opinion that biodiversity of food crops might suffer from repeated extreme weather events and monoculture crops may not be able to adapt to repeated flooding [5] [37] [40] [45] or drought [4] [26] [28] [41].

5.5. Business

Evaluating the results from question No. 11, "Climate has had significant impact on businesses in Shropshire" (**Table 2**), 36% of respondents agreed that climate change is having an impact on businesses in rural Shropshire and 52% were neutral. The rationale behind the high proportion of neutral answer is unclear. The UK derives more than 70 percent of its timber imports from EU27. In addition, about 18 percent is supplied domestically [46]. The IPCC [30] argues that, "Change in economic values will impact rural communities with the linkages between biodiversity, tourism and rural livelihoods and rural landscapes being an established one both for developing and developed countries". From the personal observation of the authors, there appears to be noticeable changes in woodland recreation [31]. Business may also be boosted by "environmental tourism" as well as by people seeking shelter from the increased temperatures and other adverse CC impacts [46].

5.6. Mitigation and Adaptation

IPCC [30] and Allen *et al.* [47] reported significant increases in the number of planned adaptation responses at the local level in rural and urban communities. Local governments play a central role in addressing the challenges of adaptation planning and implementation [30] [45]. On the other hand, a number of scholars have stressed the important role partnerships between public and private sectors could play towards CC adaptation and mitigation. In addition, it has been stated that social networks can influence vulnerability in complex ways [48]. Well networked neighborhoods have been shown to respond better in emergency situations and social isolation can increase vulnerability. A study in Sweden found out that limited co-operation between local sector organizations, lack of local co-ordination, and an absence of methods and traditions to build institutional knowledge, present barriers to managing vulnerability [30]. In addition, the study also found out that communication is vital for mitigation and adaptation to work effectively.

It might be possible for rural people in some cases to adapt to climate change by using their own knowledge, resources and networks [30]. In other cases governments and other outside actors will have to assist rural people, or plan and execute adaptation on a scale that individual rural households and communities cannot. Brisley *et al.* [49] and Laukkonen *et al.* [50] argue that most local authorities do not consider adequately the vulnerable population of the community with regard to adaptation to the impact. Examples of rural adaptations observed during this investigation includes modifying farming and fishing practices, introducing new species, varieties and production techniques, managing water in different ways, diversification of livelihoods, modifying infrastructure, and using or establishing risk sharing mechanisms, both formal and informal. Adaptation also includes changes in institutional and governance practices [30].

6. Conclusion

Evidence indicates that climate change could cause significant changes in ecosystem composition if increases in global average temperature continue unabated. As much as 30 percent of species in forest and agricultural ecosystems could be at risk of extinction. Apart from CC other factors such as land development practices, government policies as well as unsustainable agricultural practices are also contributory in causing fragmentation and extinction of species. Results from this study indicate that climate change will bring increased frequency and severity of extreme weather events to Shropshire region. As a result, increased resilience and adaptation to these climatic threats is urgently required at local (Shropshire), regional and national levels. As in other UK counties, Shropshire has recently taken a proactive step by developing a Climate Change Strategy but now faces additional challenges associated with implementation.

References

[1] Hoffman, A.J. (2011) Talking past Each Other? Cultural Framing of Skeptical and Convinced Logics in the Climate Change Debate. *Organization and Environment*, **24**, 3-33. http://dx.doi.org/10.1177/1086026611404336

[2] Weber, E.U. and Stern, P.C. (2011) Public Understanding of Climate Change in the United States. *American Psychologist*, **66**, 315-328. http://dx.doi.org/10.1037/a0023253

[3] Oreskes, N. and Conway, E.M. (2010) Merchants of Doubt: How a Handful of Scientists Obscured the Truth on Issues from Tobacco Smoke to Global Warming. Bloomsbury Press, New York.

[4] Intergovernmental Panel for Climate Change IPCC (2013) 1st Report on the Physical Science Basis of Climate Change. IPCC.

[5] Intergovernmental Panel for Climate Change IPCC (2007) Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel for Climate Change. Contribution of Working Group III, 4th Assessment Report.

[6] Department of Environment, Food and Rural Affairs DEFRA (2009) Adapting to Climate Change UK Climate Projec-

tions.

[7] Mazanec, J.A. and Strasser, H. (2001) A Nonparametric Approach to Perception-Based Market Segmentation Foundation. Springer-Verlang, Berlin.

[8] Mazanec, J.A. and Strasser, H. (2007) Perception-Based Analysis of Tourism Products and Service Providers. *Journal of Travel Research*, **45**, 387-401. http://dx.doi.org/10.1177/0047287507299576

[9] Department of Environment, Food and Rural Affairs DEFRA (2013) Faming Statistics. https://www.gov.uk/government/collections/structure-of-the-agricultural-industry#2013-publications

[10] Pearson, R.G. and Dawson, T.P. (2012) Predicting the Impacts of Climate Change on the Distribution of Species: Are Bioclimate Envelope Models Useful. *Global Ecology & Biogeography*, **12**, 361-371. http://dx.doi.org/10.1046/j.1466-822X.2003.00042.x

[11] Shropshire Rural Community Council (Shropshire RCC) (2014) Annual Report. Shropshire Rural Community Council, Shrewsbury.

[12] Fantahun, A. (2013) Impacts of Climate Change on Plant Growth, Ecosystems Services, Biodiversity and Potential Adaptation Measure. Master's Thesis, Department of Biological and Environmental Sciences, University of Gothenburg, Gothenburg. http://bioenv.gu.se/digitalAssets/1432/1432197_fantahun.pdf

[13] Lymn, N., Glasener, K.M. and Wagester, T. (2014) Agriculture, Biology and Conservation: The A, B, C's of How Nature Serves the Nation. American Society of Agronomy Crop Science, Society of America, USA.

[14] Environmental Protection Agency EPA (2014) Climate Impact on Ecosystems. http://www.epa.gov/climatechange/impacts-adaptation/ecosystems.html

[15] Bellard, C., Bertelsmeier, C., Leadley, P., Thuiller, W. and Courchamp, F. (2012) Impacts of Climate Change on the Future of Biodiversity. *Ecology Letters*, **15**, 365-377. http://dx.doi.org/10.1111/j.1461-0248.2011.01736.x

[16] Pearson, R.G., Dawson, T.P. and Liu, C. (2004) Modelling Species Distributions in Britain: A Hierarchical Integration of Climate and Land-Cover Data. *Ecography*, **27**, 285-298. http://dx.doi.org/10.1111/j.0906-7590.2004.03740.x

[17] Huntley, B. (1999) Species Distribution and Environmental Change: Considerations from the Site to the Landscape Scale. In: Maltby, E., Holdgate, M., Acreman, M. and Weir, A., Eds., *Ecosystem Management*: *Questions for Science and Society*, Royal Holloway Institute for Environmental Research, Virginia Water, 115-130.

[18] Davis, M.B. and Shaw, R.G. (2001) Range Shifts and Adaptive Responses to Quaternary Climate Change. *Science*, **292**, 673-679.

[19] McCarty, J.P. (2001) Ecological Consequences of Recent Climate Change. *Conservation Biology*, **15**, 320-331. http://dx.doi.org/10.1046/j.1523-1739.2001.015002320.x

[20] Walther, G.R., Post, E., Convey, P., Menzel, A., Parmesan, C., Beebee, T.J.C., Fromentin, J.M., Hoegh-Guldberg, O. and Bairlein, F. (2002) Ecological Responses to Recent Climate Change. *Nature*, **416**, 389-395. http://dx.doi.org/10.1038/416389a

[21] Leadley, P., Pereira, H.M., Alkemade, R., Fernandez-Manjarres, J.F., Proenca, V. and Scharlemann, J.P.W. (2010) Biodiversity Scenarios: Projections of 21st Century Change in Biodiversity and Associated Ecosystem Services. In: Bellard, C., Bertelsmeier, C., Leadley, P., Thuiller, W. and Courchamp, F. (2012) Impacts of Climate Change on the Future of Biodiversity. *Ecology Letters*, **15**, 365-377.

[22] Ray, D. (2013) Forestry Commission Research Note. Forestry Commission, Edinburgh.

[23] Power, A.G. (2010) Ecosystem Services and Agriculture: Tradeoffs and Synergies. *Philosophical Transactions of the Royal Society B—Biological Sciences*, **365**, 2959-2971. http://dx.doi.org/10.1098/rstb.2010.0143

[24] Howden, S.M., Soussana, J.F., Tubiello, F.N., Chhetri, N., Dunlop, M. and Meinke, H. (2007) Adapting Agriculture to Climate Change. *Proceedings of the National Academy of Sciences of the United States of America*, **104**, 19691-19696. http://dx.doi.org/10.1073/pnas.0701890104

[25] Zaehle, S., Bondeau, A., Carter, R.T., Cramer, W., Erhard, M., Prentice, C., Reginster, I., Rounsevell, M.A.D., Sitch, S., Smith, B., Smith, P.C. and Sykes, M. (2007) Projected Changes in Terrestrial Carbon Storage in Europe under Climate and Land-Use Change, 1990-2100. *Ecosystems*, **10**, 380-401. http://dx.doi.org/10.1007/s10021-007-9028-9

[26] Lindner, M., Maroschek, M., Netherer, S., Kremer, A., Barbati, A., Garcia-Gonzalo, J., Seidl, R., Delzon, S., Corona, P. and Kolström, M. (2010) Climate Change Impacts, Adaptive Capacity, and Vulnerability of European Forest Ecosystems. *Forest Ecology and Management*, **259**, 698-709. http://dx.doi.org/10.1016/j.foreco.2009.09.023

[27] Bishaw, B., Henry, N., Jermias, M., Abdu, A., Jonathan, M., Gemedo, D., Tewodros, A., Habtemariam, K., Ian, K. and Eike, L. (2013) Farmer's Strategies for Adapting to and Mitigating Climate Variability and Change through Agroforestry in Ethiopia and Kenya. In: Davis, C.M., Bernart, B. and Dmitriev, A., Eds., *Forestry Communications Group*, Oregon State University, Oregon.

[28] Briner, S., Elkin, C. and Huber, R. (2013) Evaluating the Relative Impact of Climate and Economic Changes on Forest

and Agricultural Ecosystem Services in Mountain Regions. *Journal of Environmental Management*, **129**, 414-422. http://dx.doi.org/10.1016/j.jenvman.2013.07.018

[29] Ray, D., Morison, J. and Broadmeadow, M. (2010) Climate Change: Impacts and Adaptation in England's Woodlands. Forestry Commission Research Note 201. Forestry Commission, Edinburgh.

[30] Intergovernmental Panel for Climate Change (IPCC) (2014) Climate Change 2014: Impacts, Adaptation and Vulnerability Contribution of the Working Group, Group 11 AR5. Cambridge University Press, Cambridge, United Kingdom, IPCC, New York.

[31] Dale, V.H., Tharp, M.L., Lannom, K.O. and Hodges, D.G. (2010) Modeling Transient Response of Forests to Climate Change. *Science of the Total Environment*, **408**, 1888-1901. http://dx.doi.org/10.1016/j.scitotenv.2009.11.050

[32] Briner, S., Elkin, C., Huber, R. and Grêt-Regamey, A. (2012) Assessing the Impacts of Economic and Climate Changes on Land-Use in Mountain Regions: A Spatial Dynamic Modeling Approach. *Agriculture*, *Ecosystems & Environment*, **149**, 50-63. http://dx.doi.org/10.1016/j.agee.2011.12.011

[33] Bellamy, R. and Hulme, M. (2011) Beyond the Tipping Point: Understanding Perceptions of Abrupt Climate Change and Their Implications. *Weather*, *Climate*, *and Society*, **3**, 48-60. http://dx.doi.org/10.1175/2011WCAS1081.1

[34] Black, C., Akintiye, A. and Fitzgerald, E. (2000) An Analysis of Success Factors and Benefits of Partnering in Construction. *International Journal of Project Management*, **18**, 423-434. http://dx.doi.org/10.1016/S0263-7863(99)00046-0

[35] Babbie, E.R. (1990) Survey Research Methods. Wadsworth Publishing Co., Belmont.

[36] Creswell, J.W. (2003) Research Design: Qualitative, Quantitative, and Mixed Method Approaches. Sage Publications, Thousand Oaks.

[37] Cork, H. (2014) Agriculture and Climate Change Interview, 1. National Farmers' Union Telford Shropshire.

[38] Blessington, J. and Shields, P. (2014) Oral Interview: Climate Change and Forestry. Shropshire Council, Shrewsbury.

[39] Herbeck, J. (2008) Biodiversity and Climate Change: 1st and 2nd Order Effects in Agriculture, Forestry and Fisheries. (2170788).

[40] Eliasch Review (2008) Climate Change: Financial Global Forest. The Stationery Office Limited on Behalf of the Controller of Her Majesty's Stationery Office. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/228833/9780108507632.pdf

[41] Petr, M., Boerboom, L.G., van der Veen, A. and Ray, D. (2014) A Spatial and Temporal Drought Risk Assessment of Three Major Tree Species in Britain Using Probabilistic Climate Change Projections. *Climatic Change*, **124**, 791-803. http://dx.doi.org/10.1007/s10584-014-1122-3

[42] Food and Agriculture Organization (FAO) (2013) Climate Change Impacts, Adaptation and Mitigation in REU Regions.

[43] Department of Environment, Food and Rural Affairs (DEFRA) (2012) Climate Change Risk Assessment for the Agriculture Sector. file://prs-store2.unv.wlv.ac.uk/home2$/in0587/home/Profile/Downloads/CCRAfortheAgricultureSector%20(1).pdf

[44] Food and Agriculture Organization (FAO) (2012) Climate Change, State of the World Forests. http://www.fao.org/docrep/016/i3010e/i3010e.pdf

[45] Food and Agriculture Organization (FAO) (2012) Forest Management and Climate Change: A Literature Review. Forests and Climate Change Working Paper10. http://www.fao.org/docrep/015/md012e/md012e00.pdf

[46] Read, D.J., Freer-Smith, P.H., Morison, J.I.L., Hanley, N., West, C.C. and Snowdon, P. (2009) Combating Climate Change—A Role for UK Forests. An Assessment of the Potential of the UK's Trees and Woodlands to Mitigate and Adapt to Climate Change. http://www.forestry.gov.uk/pdf/SynthesisUKAssessmentfinal.pdf/$FILE/SynthesisUKAssessmentfinal.pdf

[47] Allen, P., Blake, L., Harper, P., Hooker-Stroud, A., James, P. and Kellner, T. (2013) Zero Carbon Britain, Rethinking the Future. http://library.uniteddiversity.coop/Climate_Change/Zero_Carbon_Britain_2013.pdf

[48] Preston, I., Banks, N., Hargreaves, K., Kazmierczak, A., Lucas, K., Mayne, R., Downing C. and Street, R. (2014) Climate Change and Social Justice: An Evidence Review. http://www.jrf.org.uk/sites/files/jrf/climate-change-social-justice-full.pdf

[49] Brisley, R., Welstead, J., Hindle, R. and Paavola, J. (2012) Socially Just Adaptation to Climate Change. http://www.jrf.org.uk/sites/files/jrf/climate-change-adaptation-full_0.pdf

[50] Laukkonen, J., Blanco, P., Lenhart, J., Keiner, M., Cavric, B. and Kinuthia-Njenga, C. (2009) Combining Climate Change Adaptation and Mitigation Measures at the Local Level. *Habitat International*, **33**, 287-292.