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Climate change and agricultural workers' health in Ecuador: occupational exposure to UV radiation and hot environments

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Abstract
Climate change is a global concern but little is known about its potential health effects in workers from non-industrialized countries. Ecuadorian workers from the coast (hot environments) and Andean region (elevated UV radiation) might be at particular risk of such effects. In the Andean region, measurements of UV index show maximum levels exceeding 11, a level considered being extreme according to the WHO. Also, an increased incidence of skin cancer was reported the last decennium, this being the second most common cancer type in men and women. In the coast, a high reported prevalence of kidney disease in agricultural workers is suggested to be related to exposure to hot temperatures. The scarce data available on occupational health in Ecuadorian agricultural workers raise the need for further investigation. Data worldwide shows an increasing prevalence of UV radiation- and heat stress-related illnesses in agricultural workers and urges the adoption of preventive measures.

Key words
- climate change and occupational health
- agricultural workers
- UV radiation
- heat stress
- Ecuador

INTRODUCTION

Climate change is a global concern [1]. However, little is known about potential effects of climate change on workers' health, particularly in non-industrialized countries. Ecuador has diverse climatic regions, two of them being the most susceptible regarding global climate changes: the Ecuadorian coast, at the sea level and with tropical climate, and the Andean mountains, up to about 3000 meters above the sea level. Climate change-related increases in temperature (the Ecuadorian coast) and ultraviolet (UV) radiation (Andean region) are of particular concern [2].

The aim of this article was to review the available literature and data on occupational health in relation to exposure to UV radiation and hot temperatures in Ecuador.

Hot environments and heat stress-related illnesses

Temperature has increased globally and this is particularly evidenced in Ecuador by a decrease of 31% in the glaciers of one of the highest volcanoes, Cotopaxi, in the last 30 years [3]. For agricultural workers, occupational exposure to hot environments is another major climate change-related problem. Indeed, agricultural workers are one of the working groups at highest risk of heat stress, followed by construction and manufacturing workers, miners, armed forces personnel and fire-fighters [4]. In the Ecuadorian coast, agricultural workers usually perform their activities under poor working conditions, at temperatures between 25 and 35 °C degrees and humidity of 60-80%, increasing the risk of heat stress.

Agricultural workers are particularly at risk of heat stress due to the exposure to hot environments [4]. Ecuador, with about 14 500 000 inhabitants, is known for its varied agricultural production where, in total, more than 1 million inhabitants are employed *(Table 1)*. About half of them (603 366) are employed in non-perennial crops and the other half in perennial crops. Sugarcane cutters (about 16 500 workers) perform most of their activities outdoors, in a tropical climate (hot and wet) and without the provision of sufficient and adequate water and electrolytes. Also, in some sugarcane plantations, workers must cut at least 6.5 tons of sugarcane per day to keep their job. These working conditions are kept during the cane harvest period (between July and December, 6 months, each year) and for several years, at least those workers who are not fired due to a bad health condition. In consequence, workers repetitively suffer dehydration and frequent episodes of a particular syndrome called "revival" (in Spanish "avivamiento"). This condition is a consequence of heat stress and is characterized by the sudden onset of cramps in upper

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Table 1
Estimated number of workers employed in agricultural activities in Ecuador by December 2015*

Agricultural occupation	Estimated total number of workers
Non-perennial crops	
Cereals (*e.g.* wheat, corn, quinoa)	252 219
Vegetables (*e.g.* beans, broccoli, potatoes, pumpkin)	157 804
Rice	104 250
Flower seeds	61 168
Sugar cane	16 618
Tobacco	7094
Plants grown in vivarium	3884
Cotton and other textile plants	779
Perennial crops	
Tropical fruits (*e.g.* banana, passion fruit, mango, pineapple)	241 645
Coffee, tea, cocoa	216 516
African palm and other oily plants	33 427
Other fruits and nuts (*e.g.* strawberries, physalis, almonds).	23 350
Citrus fruits	12 194
Medicinal plants	6402
Other perennial plants (*e.g.* palm heart, rubber, latex)	5995
Stone fruits and fruits with seeds/pits (*e.g.* apple, pear)	1877
Grapes	349
Total	**1 145 571**

*Information was obtained from the National Institute of Statistics and Censuses (ENEMDU-INEC) and from the Centre of Labor Studies from the Ministry of Labor of Ecuador (CET).

and lower limbs. Affected workers are forced to immediately seek for medical care and, although this condition seems to usually have a quick recovery (within a few hours after I.V. hydration), workers are unable to work again [5]. Also, in this occupational group, a higher prevalence of kidney diseases has been reported [5].

A number of authors have evaluated some of the consequences of heat stress in agricultural workers in several countries and report an increased rate of heat stress-related morbidity and mortality among agricultural workers as compared with non-agricultural workers [4, 6]. In particular, there is great concern about an epidemic chronic kidney disease reported in agricultural workers in Mesoamerica, Thailand and Sri Lanka [6-10], whose working conditions are similar to those of Ecuadorian agricultural workers.

The exact mechanisms and factors involved in this type of chronic kidney disease are still unclear. It is hypothesized that repeated heat stress and dehydration, followed by loss of sodium and potassium might be a major causative pathway [10]. Nonetheless, the contribution of other factors such as the exposure to agrochemicals and metals, the excess use of nonsteroidal anti-inflammatory (NSAIDs) and other nephrotoxic drugs, fructose consumption in rehydration fluids, infections, alcohol as well as genetic susceptibility, has not been totally ruled out [10].

The mechanism how heat dehydration could produce a kidney damage is suggested to be through glomerular ischemia, possibly aggravated by the intake of NSAIDs, as well as through an impairment of the renin-angiotensin system due to excessive sweating leading to repeated losses of salts [11]. This is supported by findings in sugarcane workers from Brazil and El Salvador showing higher plasma creatinine concentrations after the shift [12], as well as higher serum uric acid and urinary osmolality and lower urinary pH [13]. Also, another recent study in sugarcane in Nicaragua showed higher serum creatinine and urea concentrations and lower glomerular filtration rate already after only 9 weeks of harvest [14].

Another potential mechanism involved in this pathology could be glomerular hypertension, due to the increase in the uric acid concentrations in blood (hyperuricemia), and a direct injury to the renal tubules by dihydrate urate crystals as a result of increased urinary uric acid concentrations [15]. All these also as a result of the exposure to heat stress accompanied by the poor working conditions, leading to repeated water and volume depletion and excessive physical activity.

Still, more research is needed in order to understand better the potential mechanisms involved, as well as susceptibility factors. So far, the best known prevention seems to be the adequate hydration and limitation of the exposure to heat stress.

UV radiation and skin cancer in Ecuador

Climate change may increase UV radiation levels at ground by affecting the expected recovery of the stratospheric ozone depletion (produced by some greenhouse gases like CFCs), or by altering UV absorbing tropospheric gases, aerosols, and clouds in the atmosphere [16].

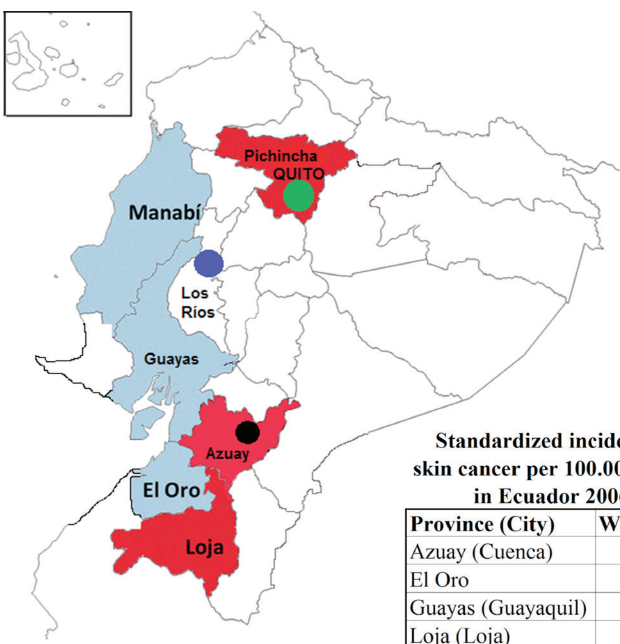
UV radiation A (UVA), B, and C are classified as carcinogenic to humans (Group 1) by the International Agency for Research on Cancer [17]. It is known that exposure to UV radiation increases with decreasing the distance to the equator and that each 300 meters increase in altitude, from the sea level, increases the UV radiation by about 4% [18]. In consequence, the capital of Ecuador, Quito, and the interandean region, both located at about 2800-3000 meters above the sea level, are exposed to UV levels about 40% higher than those in low-land regions.

The Global Solar UV Index (UVI) is a tool created by the World Health Organization, the World Meteorological Organization, the United Nations Environment Programme and the International Commission on Non-Ionizing Radiation Protection and used to describe the level of solar UV radiation at the Earth's surface. It is classified in 5 categories from 0 to > 11 where: ≤ 2 are considered low, 3-5 moderate, 6-7 high, 8-10 very high and ≥ 11 extreme. Thus, the higher the values of the index, the greater the potential for damage to the skin and eye [19].

In Ecuador, as part of the research project "National Network for Solar UV Radiation Monitoring and Development of Validation Models and Prognosis of UV Parameters", developed by the National Institute of Meteorology and Hydrology (INAMHI) and supported by the National Secretary of Higher Education, Science and Technology (SENESCYT), several meteorological stations were installed along the country aiming at recording UV and ozone data. For the present article, data from three stations, those with most data available during 2014 and 2015, are presented. Two of these stations were installed in susceptible areas in the Andean region and one in the Ecuadorian coast, with potentially lower solar UV radiation. Specifically, solar UV radiation sensors (Kipp&Zonen, Model UV-S-AE-T) were installed in: Izobamba (Province of Pichincha, Andean region, latitude: -0.366089, longitude: -78.555061, altitude: 3085 masl), Cuenca (Province of Azuay, Andean region, latitude: -2.897463, longitude: -79.003108, altitude: 2587 masl) and Pichilingue (Province of Los Ríos, Coast, latitude: -1.074361, longitude: -79.492944, altitude: 81 masl) *(Figure 1)*. The radiometric data involved measurements of both UVA and UVE (Erythemal UV) but only UVE was used to calculate the UVI. Measurements were recorded in the three meteorological stations every day from 10:00 am to 4:00 pm. The meteorological stations are continuously measuring UVE and measurements from nine of the stations are available in quasi-real time at the INAMHIs webpage (www.serviciometeorologico.gob.ec).

In Izobamba *(Figure 2A)*, the maximum levels of UVI obtained from January till August 2015 were about 0.5 to 2.5 units higher than those obtained in the same months in 2014, while no clear patterns were observed in the remaining months. The highest UVI value measured in 2014 was 17.2 (22 October) while the highest UVI value in 2015 was 19.6 (7 March). The latter was reported as the highest UVI value measured in 2015 in Ecuador. The frequency of measurements above 8 in 2015 appeared to be 2 to 3-fold higher than those obtained in 2014 *(Figure 2B)*.

In Cuenca *(Figure 2C)*, maximum UVI values followed similar patterns in 2014 and 2015 with slightly higher values from July till November 2015 than those registered in the same period of time in 2014, and higher UVI values in January and February 2014 compared with the same months in 2015. UVI data in March and April 2014 was not available. In 2014, the highest UVI value recorded was 18.256 (11 February) which was



Standardized incidence rate of skin cancer per 100.000 individuals in Ecuador 2006-2010.

Province (City)	Women	Men
Azuay (Cuenca)	23	19
El Oro	20	15
Guayas (Guayaquil)	14	16
Loja (Loja)	26	23
Manabí	15	14
Pichincha (Quito)	30	36

Figure 1
Meteorological stations in Izobamba (green), Cuenca (black) and Pichilingue (blue) and standardized incidence rate of skin cancer per 100 000 individuals in Ecuador 2006-2010. Red colors indicate the provinces with the highest reported standardized incidence rates of skin cancer[a].

[a]Information was obtained from the Society for Fight Against Cancer in Ecuador (SOLCA) and from the National Institute of Meteorology and Hydrology (INAMHI).

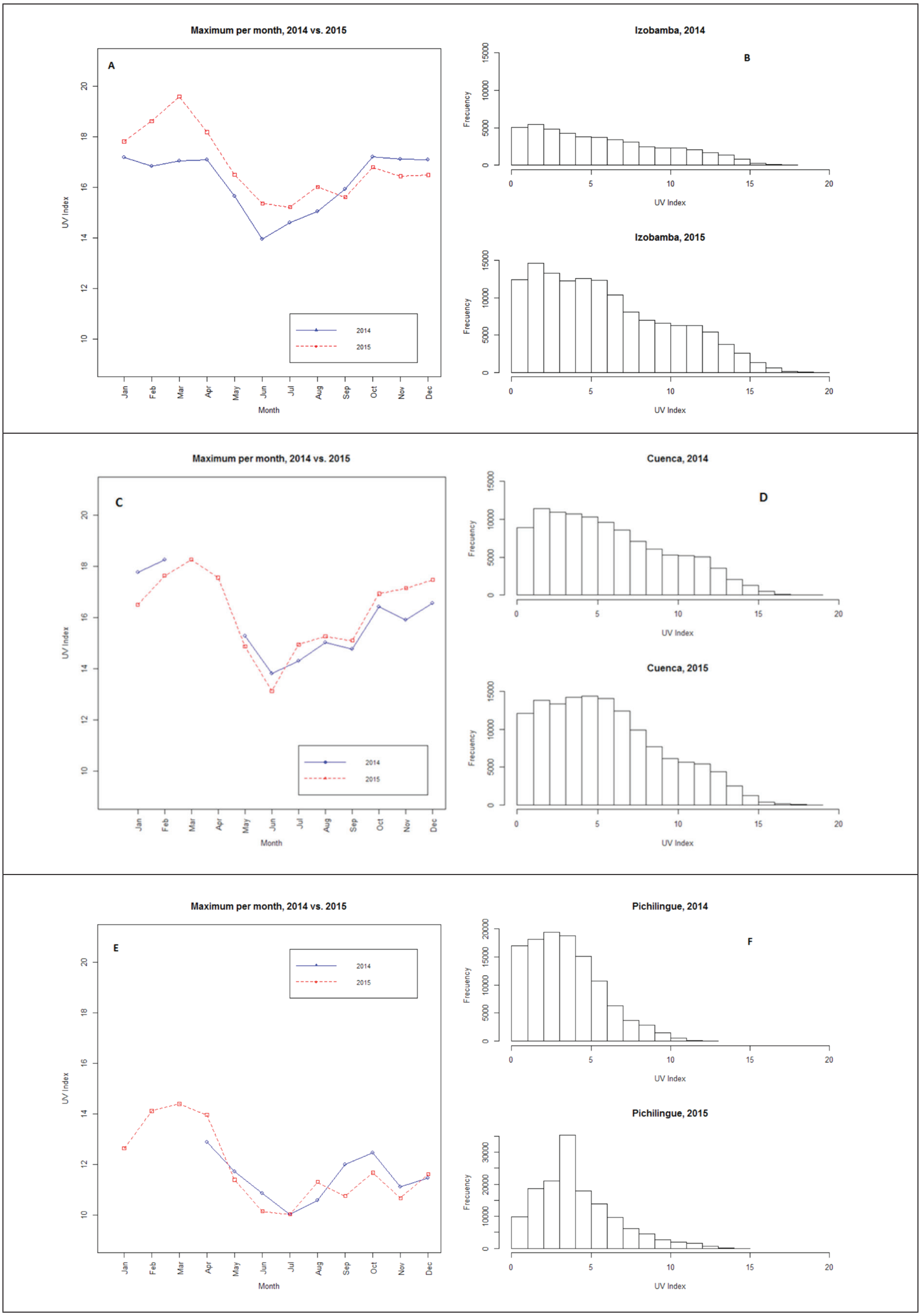


Figure 2
Maximum UV Index measurements by month and distribution of all available measurements in 2014 and 2015 in Izobamba (A, B), Cuenca (C, D) and Pichilingue (E, F).

similar to the maximum obtained in 2015 (18261; 11 March). *Figure 2D* also shows similar patterns of distribution of the measurements obtained in both years, with slightly higher frequency of UVI measurements of 3-5 in 2015.

In Pichilingue *(Figure 2E)*, patterns of measurements in 2014 and 2015 were also similar, with higher values in June, September, October and November 2014, compared with those in 2015. Data from January till March 2014 was not available. The highest UVI value obtained in 2014 was 12.88 (29 April) while it was 14.4 in 2015 (12 March). *Figure 2F* shows a clear higher frequency of higher UVI measurements obtained in 2015, compared with 2014.

All obtained maximum UVI values in Izobamba, Cuenca and Pichilingue were above 11, *i.e.* above the value considered to be extreme according to the World Health Organization and the International Commission on Non-Ionizing Radiation Protection [19].

There is sufficient evidence in humans that UV radiation increases the risk for basal cell carcinoma, non-melanocytic cell carcinoma (basal and squamous) and melanoma, reason why UV radiation A, B, and C are classified as carcinogenic to humans (Group 1) by the International Agency for Research on Cancer [17]. In Quito, Ecuador, between 2006 and 2010, skin cancer showed an increased incidence and prevalence, placing this type of cancer as the second most common cancer among men (after prostate cancer) and women (after breast cancer), with an increasing trend over the last ten years [20]. The same trend has been seen for Cuenca and Loja, also located in the Andean region, while the incidence is much lower for cities located in provinces in the coast such as in Guayas, Manabí and El Oro *(Figure 1)*. Overall, squamous cell carcinoma is highly prevalent (20%) although its frequency is around one third of that for cases of basal cell skin carcinoma (65%), while malignant melanoma constitutes about 10% of all skin carcinomas [20]. In the city of Cuenca, cases often occur in agricultural workers. Studies in workers with outdoors occupations and exposure to UV radiation have reported an increased risk of skin cancer [21, 22]. As shown for other countries [23], this is of particular concern for Ecuadorian farmers working in the interandean region, who are, thus, exposed to high UV radiation levels. Although cases reported by the Society for Fight Against Cancer in Ecuador (SOLCA; Sociedad de Lucha contra el Cáncer del Ecuador, www.solca.med.ec) are thoroughly diagnosed, even histopathologically, and information is sometimes available regarding the occupation, there is still an underreporting of cases, scarce data on exposure to UV and lack of analysis and interpretation of the available data from an occupational health perspective.

CONCLUSIONS

Considering the present and predicted increases in global air pollution and temperature, climate change might aggravate the exposure to hot weather and UV radiation in the coming years. Agricultural workers in Ecuador and worldwide exposed to UV radiation and hot temperatures are at higher risk for morbidity and mortality. The increasing prevalence of UV radiation- and heat stress-related illnesses in agricultural workers worldwide and the lack of data on occupational health in agricultural workers in Ecuador raise the need for further investigation and for adoption of preventive measures.

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Conflict of interest statement

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