Brendan Long

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Introduction: Prometheus

According to Greek mythology, Prometheus stole fire from the gods and gave it to humans. He observed that each of the other animals had an advantage, but humans had none. Where were our claws to protect us, our wings to fly or our furs to keep us warm? Prometheus took it upon himself to give us an advantage: fire.

With fire we were on the up. From our lowly and perilous origins, the advantage of fire elevated humankind to greatness.

From our earliest beginnings, fire has provided us with warmth, light and cooked food. Fire allowed us to make the materials upon which we built civilization, namely, bricks, glass, bronze and steel. Fire, today, provides nine-tenths of our global needs in energy.[1]

Humankind is choosing to extinguish the gift of Prometheus because the burning of fire emits carbon dioxide.

Fire was written to provide thought provoking perspectives by tracing the history of humanity and of our Earth through the storyline of fire.

Fire challenges conventional thinking and brings the lessons of history to the heart of the issues that matter today: addressing global warming, ending global hunger and protecting wildlife.

This is the story of fire.

[1] **World Energy Balances 2020 (Data for 2018)** – International Energy Agency – July 2020

Free Sample: Farming

4. Farmland: Wildfire Boundary

Wildfire dynamics change abruptly at the boundary between farmland and wilderness, but what are the root causes driving the expansion of farmland and why is this expansion currently most pronounced in the Tropics? Those questions will be answered in this section.

In this section we will also gain an understanding of the importance of agricultural yields. In the section "From Fire: Human Development" we will gain an appreciation of the role that the human use of fire has played, and continues to play, in increasing agricultural yields.

Farmland: the Basis of Civilization

Since the acquisition of language some 80,000 years ago[2], the most significant development in our human trajectory has been the development of agriculture – farming. The most significant and clearly evidenced cause of the Agricultural Revolution was the end of the most recent ice age. If we accept that humans have been present in our current anatomical form for the last 300,000 years, we would have spent the vast majority of our existence struggling to survive against cold and ice. This is known because the last 300,000 years have generally been glacial periods. Prior to about 18,000 years ago, global temperatures, as estimated by the US National Oceanic and Atmospheric Administration, were as much as 7.5° Celsius (13.5° Fahrenheit) colder than they are today.[3]

Glaciers occur when snow does not melt away in the summer over many years, which allows it to accumulate, compact and turn into ice. Over the years, as more snow accumulates and is transformed

[2] **The Unfolding of Language** – Guy Deutscher – Holt Paperbacks – January 2005;
The truth about language: what it is and where it came from – Michael Corballis – The University of Chicago Press – 2017; and
Why Only Us Language and Evolution – Robert C. Berwick and Noam Chomsky – The MIT Press – 2016

[3] **Glacial-Interglacial Cycles** – National Oceanic and Atmospheric Administration – https://www.ncdc.noaa.gov – Accessed: July 2020

into ice, glaciers can thicken into massive ice sheets several kilometers high.

During the last glacial period, what is now the city of New York was entirely covered in ice sheets. Those ice sheets are estimated to have been higher than the skyscrapers that now give that city its skyline.[4]

Recent research has provided incredibly granular knowledge of the ice-sheet cover over Britain and Ireland. The maximum extent of the most recent ice sheets over Britain and Ireland occurred some 22,000 years ago. At that time, Ireland and Scotland were entirely covered by ice and Wales was largely covered in ice too. Ice sheets in England came as far south as to almost, but not quite, cover the locations of the current cities of Leeds, Manchester and Sheffield.[5] However, around 15,000 years ago global temperatures began to rise. As they did, great areas of the Earth that had been covered by ice were transformed into fertile forests and grasslands. Britain was generally free of ice from 11,700 years ago.

The beginning of the Agricultural Revolution could not have been triggered only by a warmer climate because there were two prior interglacial periods over the last 300,000 years during which estimated temperatures were actually higher than they are today (Figure 8), but there is no evidence of a shift to farming during any of the prior interglacial periods.[6]

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[4] **How the Ice Age Shaped New York** – William J. Broad – New York Times – 5 June 2018

[5] **BRITICE Glacial Map, version 2: a map and GIS database of glacial landforms of the last British–Irish Ice Sheet** – Chris D. Clark, Jeremy C. Ely, Sarah L. Greenwood, Anna L. C. Hughes, Robert Meehan, Iestyn D. Barr, Mark D. Bateman, Tom Bradwell, Jenny Doole, David J. A. Evans, Colm J. Jordan, Xavier Monteys, Xavier M. Pellicer, Michael Sheehy – BOREAS An International Journal of Quaternary Research – 29 August 2017

[6] **Glacial-Interglacial Cycles** – National Oceanic and Atmospheric Administration – https://www.ncdc.noaa.gov – Accessed: July 2020; and
Northern Hemisphere forcing of climatic cycles in Antarctica over the past 360,000 years – Kenji Kawamura, Frédéric Parrenin, Lorraine Lisiecki, Ryu Uemura, Françoise Vimeux, Jeffrey P. Severinghaus, Manuel A. Hutterli, Takakiyo Nakazawa, Shuji Aoki, Jean Jouzel, Maureen E. Raymo, Koji Matsumoto, Hisakazu Nakata, Hideaki Motoyama, Shuji Fujita, Kumiko Goto-Azuma, Yoshiyuki Fujii & Okitsugu Watanabe – Nature – 23 August 2007

Glacial and interglacial periods *Figure 1*

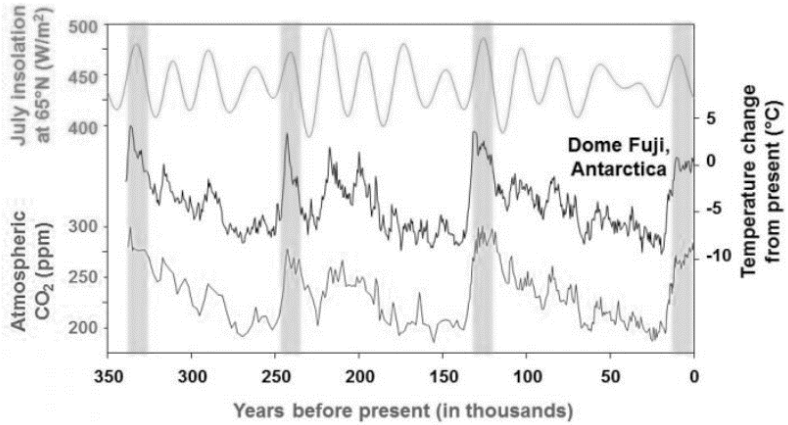

Image Credit: US National Oceanic and Atmospheric Administration[7]

As we have seen, we acquired language (the cognitive ability to code ideas in our minds) some 80,000 years ago. The first interglacial period to have occurred since acquiring language is the one in which we are currently living. Having acquired language, all that was needed to kick-start the Agricultural Revolution and the emergence of human civilizations was a change in global temperatures and the corresponding retreat of ice sheets.

Prior to the end of the last ice age, humans lived in small nomadic hunter-gatherer communities. 23,000 years ago, the European-wide human population was less than 200,000 by some estimates.[8]

From that statistic alone we know that survival was not to be taken for granted during the last ice age. The combination of less food and considerably colder temperatures would have made life extremely difficult indeed.

As the ice sheets retreated, humans were thriving. Food sources became more plentiful and our hunting skills were honed to make the

[7] **Glacial-Interglacial Cycles** – National Oceanic and Atmospheric Administration – https://www.ncdc.noaa.gov – Accessed: July 2020

[8] **Human population dynamics in Europe over the Last Glacial Maximum** – Miikka Tallavaara, Miska Luoto, Natalia Korhonen, Heikki Järvinen and Heikki Seppä – Proceedings of the National Academy of Sciences of the United States of America – 7 July 2015

most of the opportunity. Human population levels increased during this period. However, at some point, the trend of rising human population levels created an existential threat for many humans: There was simply not enough food to support a continuously growing population.

Land is limited and hunting and gathering requires a tremendous amount of land to support a limited number of people. By some estimates, our Earth can support a population of only 10 million hunter-gatherers.[9]

From the time that humans acquired language to 1,000 years ago, 177 large mammals went extinct in what is known as the global Megafaunal Extinction.[10] This extinction event started well before the transition from hunter-gatherers to farmers began; however, it would surely have been intensified by rising populations of hungry hunter-gatherers.[11] As a result of these extinctions, hunter-gatherers lost sources of food.

With insufficient food to support their growing populations and with sources of food diminishing, many humans were at risk of perishing.

From experimental origins and across the world, societies gave up their nomadic ways to become sedentary agriculturalists because agriculture provided a means of ensuring that growing human populations would have enough food. There is no evidence to suggest that the quality of food or the lifestyles of early farmers was better than it had been for hunter-gatherers. However, farming reduced the risks of hunger and starvation. Agriculture supported ever-increasing human populations making a return to nomadic ways impractical.

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[9] **Hunter-gatherer populations inform modern ecology** – Joseph R. Burger and Trevor S. Fristoe – Proceedings of the National Academy of Sciences of the United States of America – 6 February 2016

[10] **Global late Quaternary megafauna extinctions linked to humans, not climate change** – Christopher Sandom, Søren Faurby, Brody Sandel and Jens-Christian Svenning – Proceedings of the Royal Society – 22 July 2014; and
Extinction of large mammals in the Late Quaternary Ice Age – Adrian Lister – Natural History Museum – https://www.nhm.ac.uk – Accessed: February 2021

[11] **Population reconstructions for humans and megafauna suggest mixed causes for North American Pleistocene extinctions** – Jack M. Broughton and Elic M. Weitzel – Nature Communications – 21 December 2018

The earliest farming communities emerged in:[12]

i) the eastern Mediterranean, from which area farming extended quickly to adjacent areas with fertile land;

ii) Central Mexico; and

iii) the middle Yangtze River region in China.

The archaeological evidence from the eastern Mediterranean region provides the best record of the early transition of hunter-gatherers into sedentary farmers. The transition to a sedentary lifestyle was a slow transition which started with the harvesting of wild cereals. Cereal grains keep for a long time, which is critically advantageous. The possibility of storing large amounts of grain would have been one important reason to have abandoned an entirely nomadic existence. The first settled people of the area, the Early Natufians, lived 12,500 to 11,000 years ago and they built stone houses that had a resemblance to modern houses.[13]

The Agricultural Revolution consisted of applying human ingenuity to increase food production from a limited area of land. For example, the primitive Natufian sickles increased yields by reducing waste.

The first farmers intended only to produce enough food to sustain their communities, but soon they were creating a surplus of food. This allowed people to engage in other specialist activities and to move to newly emerging towns. From these towns and from the freedom provided by a surplus of food rose social structures, commerce, armies, professional clergy, specialization of labor and governments. Indeed, the great civilizations of antiquity all rose up as a product of the Agricultural Revolution – as have our own.

The mathematical logic of agricultural yields and land use can be shown by example. In 2017, the global average yield for wheat fields was 3.46 metric tons per hectare and for rice that figure was 3.10 metric tons per hectare. For reference, a hectare is an area of land equal to 100 meters by 100 meters or roughly 2.5 acres. In the same year, the world consumed 761.3 million metric tons of wheat and

[12] **The Natufian Culture in the Levant, Threshold to the Origins of Agriculture** – Ofer Bar-Yosef – Evolutionary Anthropology – 7 December 1998

[13] **The Natufian Culture in the Levant, Threshold to the Origins of Agriculture** – Ofer Bar-Yosef – Evolutionary Anthropology – 7 December 1998

512.4 million metric tons of rice.[14] For any particular food, dividing the amount of food we need by the agricultural yield for that food indicates how much land we need to satisfy our requirements. To satisfy our needs in wheat, we need 2.2 million square kilometers (849 thousand square miles) of farmland – equivalent to 3.2 times the surface area of the state of Texas, USA. To satisfy our needs in rice, we need 1.7 million square kilometers (638 thousand square miles) of farmland – equivalent to 2.4 times the surface area of the state of Texas, USA.

The human population has grown to 7.7 billion and is expected to grow by a further 42% by the year 2100.[15] If agricultural yields do not increase correspondingly by that time, in order to grow enough food, we will need more farmland. In effect, agricultural yields must increase over the next century to avert the destruction of wildlife on a colossal scale.

Farmland: Taken from Wilderness

63% of the Earth's land surface is suitable for the growth of forests or grasslands. Of that land, humans have permanently settled 56%.[16]

We use 93% of the land we have permanently settled for agriculture and the remaining 7% for urban and infrastructure related purposes. 30% of agricultural land is used for crops and the remaining 70% is used as pastureland for grazing livestock.[17]

By some estimates, three-quarters of the Earth's land environment has been significantly altered by human actions.[18]

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[14] **Agricultural Outlook 2019-2028** – OECD/Food and Agricultural Organization UN – https://stats.oecd.org – Accessed: March 2020
[15] **World Population Prospects 2019** – United Nations – Department of Economic and Social Affairs
[16] **Assessing Global Land Use** – Stefan Bringezu, Helmut Schütz, Walter Pengue, Meghan O´Brien, Fernando Garcia, Ralph Sims, Robert W. Howarth, Lea Kauppi, Mark Swilling and Jeffrey Herrick – United Nations Environment Programme – 2013
[17] **Assessing Global Land Use** – Stefan Bringezu, Helmut Schütz, Walter Pengue, Meghan O´Brien, Fernando Garcia, Ralph Sims, Robert W. Howarth, Lea Kauppi, Mark Swilling and Jeffrey Herrick – United Nations Environment Programme – 2013
[18] **Nature's Dangerous Decline 'Unprecedented' Species Extinction Rates 'Accelerating'** – United Nations, Intergovernmental Science-Policy on Biodiversity and Ecosystem Services – 6 May 2019

Since the beginning of the Agricultural Revolution some 12,500 years ago, the expansion of farmland and urbanization has displaced wildlife.

Habitat loss has been, is, and will be, the principal threat to terrestrial ecosystems – wildlife – because without land wildlife cannot exist.

Conservationists have long known that habitat loss is the single greatest threat to wildlife. The World Wildlife Fund and the National Wildlife Federation of the United States have both drawn attention to this issue by stating that habitat loss is the number-one threat to wildlife.[19]

In 2019, for the first time ever, the United Nations sponsored a global intergovernmental project to assess and rank risks to wildlife. That research group determined that globally the single most important risk to wildlife is habitat loss.[20]

For reference, according to that research project, the second greatest threat to wildlife is the direct exploitation of animals and the third greatest threat to wildlife is global warming.

Deforestation for the purposes of creating farmland causes extreme transformations of landscapes. Since the launch of NASA's Terra satellite, it has been possible to track changes to tree cover on a global basis. Bearing in mind that satellite data always provides completely surprising results, let us take a look at the rates of deforestation globally.

Globally, and contrary to prevailing expectations, the Earth's forested surface area has actually *increased* at a rate of 175 square kilometers (68 square miles) *per day* over the 35 years to 2016, net of losses, based on satellite data. In total, over that period the forested surface area of the Earth has increased by 7% or 2.24 million square

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[19] **"Habitat Loss Poses the Greatest Threat to Species" Habitat Loss** – World Wildlife Fund – https://wwf.panda.org/ – Accessed: July 2020; and
Threats to Wildlife – The National Wildlife Federation – https://www.nwf.org/ – Accessed: July 2020

[20] **Nature's Dangerous Decline 'Unprecedented' Species Extinction Rates 'Accelerating'** – United Nations, Intergovernmental Science-Policy on Biodiversity and Ecosystem Service – 6 May 2019

kilometers (864 thousand square miles), net of losses.[21] In contrast to widely held perceptions, in general, globally, forests are thriving. This will be assessed in more detail in the section "From Fire: Carbon Dioxide Fertilization".

In contrast to the global trend, in the Tropics forests are in decline.

Based on satellite data, deforestation has been most pronounced in the southern Tropics. Brazil recorded the highest rate of tree cover loss over the period (1982-2016) with a loss of 385 thousand square kilometers (149 thousand square miles), representing a percentage decline of 8% over the period.

The satellite data measures tree cover and does not distinguish between a forest and a tree plantation. In the Tropics deforestation is occurring partly to cultivate fruit that grows in trees, such as palm fruits. Therefore, the satellite data under-represents deforestation in the Tropics.

Using African data that has been collected by on-the-ground surveys and sorting national data by geography shows that in the decade ending in 2010 the African Tropics lost 326 thousand square kilometers (126 thousand square miles) of forest, representing a loss of 4.9% of forested land over that decade.[22]

The key points are as follows:

i) Habitat loss represents *by far* the single most important threat to wildlife globally.

ii) Wildlife has been losing habitat due to the expansion of the Agricultural Revolution for the last 12,500 years as people have settled land, principally for agricultural and urban uses.

iii) Today, habitat loss is concentrated in the Tropics.

[21] **Global land change from 1982 to 2016** – Xiao-Peng Song, Matthew C. Hansen, Stephen V. Stehman, Peter V. Potapov, Alexandra Tyukavina, Eric F. Vermote & John R. Townshend – Nature – 8 August 2018

[22] **Forests, Trees, and Woodlands in Africa** – Africa Region, World Bank – 11 October 2012

Farmland: to End Hunger

Let us turn our attention to the root cause of the Agricultural Revolution: hunger.

Having grown up in the 1980s, I can remember that in that decade hunger was a major global concern. Surely, hunger is not being talked about as much today because it has been eradicated; let us take a look at the scorecard.

Based on data from the United Nations, in the 1970s the number of people suffering from malnourishment globally was reduced by 37 million people. By the end of the 1980s the number of people suffering from malnourishment had fallen by a further 100 million.[23] However, in the three decades since the 1980s to the present no more than 3 million people have left hunger globally based on data from the same source.[24] Today, 820 million people continue to suffer from hunger.[25] In essence, after two decades of profound improvement in the alleviation of malnourishment, there has been a period of three whole decades during which there has been no substantive improvement in malnourishment globally.

In a report entitled "The Neglected Crisis of Undernutrition: Evidence for Action" the United Kingdom's Department for International Development indicated that "nutrition fundamentally determines life chances and people's ability to convert opportunities into outcomes."[26] That puts into focus the World Health Organization's estimate that 144 million children under the age of five will be stunted, implying their physical and mental development

[23] **Undernourishment around the world, Counting the hungry: trends in the developing world and countries in transition; The State of Food Insecurity in the World 2006** – Food and Agriculture Organisation of the United Nations – 2006

[24] **The State of Food Security and Nutrition in the World 2019** – Food and Agriculture Organization of the United Nations, International Fund for Agricultural Development, UNICEF, World Food Programme and World Health Organization – 2019

[25] **The State of Food Security and Nutrition in the World 2019** – Food and Agriculture Organization of the United Nations, International Fund for Agricultural Development, UNICEF, World Food Programme and World Health Organization – 2019

[26] **The Neglected Crisis of Undernutrition: Evidence for action** – UKAID, UK Department of International Development – 2009

will be damaged permanently due to a lack of food.[27] That figure represents 21.3% of young children globally.[28] Today, 45% of child deaths globally are associated with malnutrition according to the World Health Organization.[29]

The United Nations also estimated that, in addition to the people who are hungry today, there are 2 billion people who are experiencing moderate to severe food insecurity. This implies that a great many people are at risk of being unable to assure their food in sufficient quantity and quality.

820 million hungry. 144 million stunted children. 2 billion experiencing food insecurity. No improvement in three decades.

That is what you call one utterly repulsive scorecard.

In remarkable contradiction to that assessment, many organizations that track hunger indicate that decade-over-decade hunger has been in decline.[30] What is going on?

As the number of people suffering from hunger has remained unchanged for the last three decades, the global population has grown. As a result, the percentage of the global population suffering from hunger has fallen. On that basis, many organizations have communicated that hunger is in decline. Further confounding public perception, there are multiple indicators that are used to estimate the extent of global malnourishment.[31]

The key point to retain is that, despite many statements to the contrary, since the 1980s the number of our fellow humans suffering from hunger globally has not fallen meaningfully and today,

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[27] **World Health Statistics 2020** – World Health Organization: monitoring health for the SDGs, sustainable development goals – 2020

[28] **Child Stunting** – World Health Organization – https://www.who.int – Accessed: March 2021

[29] **Malnutrition** – World Health Organization – https://www.who.int – Accessed: March 2021

[30] **The State of Food Security and Nutrition in the World 2019** – Food and Agriculture Organization of the United Nations, International Fund for Agricultural Development, UNICEF, World Food Programme and World Health Organization – 2019

[31] **Hunger and Food Insecurity** – United Nations Food and Agriculture Organization – http://www.fao.org/ – Accessed May 2021

according to the United Nations, “More than 820 million people do not have enough food to eat.”[32]

Of most alarm, the United Nations has indicated that it expects hunger to worsen significantly in the current decade as measured by the number of people suffering from hunger and by the percentage of the global population suffering from hunger.[33]

In contrast to the widely held perception that hunger globally is not an issue of primary concern, it represents the greatest humanitarian crisis of modern times. Critically, hunger is also a root cause of many other global tragedies, inclusive of the large-scale destruction of wildlife habitat, and correspondingly, of wildlife.

Let us now turn our attention to where global hunger and extreme poverty are geographically concentrated.

Two Finnish professors had the idea of plotting measures of human development against lines of latitude from the North Pole, through the Equator, to the South Pole. Based on their data, extreme poverty is distinctly concentrated in the Tropics.[34]

Currently, 670 million people living in the Tropics are estimated to be suffering from extreme poverty.[35] 85% of the poorest people in the world live in the Tropics.[36] It is projected that as many as 67% of the world’s children under the age of 15 will be living in the Tropics by 2050.[37]

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[32] **The State of Food Security and Nutrition in the World 2019** – Food and Agriculture Organization of the United Nations – http://www.fao.org/state-of-food-security-nutrition – Accessed: May 2021

[33] **Hunger and Food Insecurity** – United Nations Food and Agriculture Organization – http://www.fao.org/ – Accessed May 2021

[34] **The world by latitudes: A global analysis of human population, development level and environment across the north–south axis over the past half century** – Matti Kumma and Olli Varis – Applied Geography – April 2011

[35] **State of the Tropics 2020 Report** – Sandra Harding, Ann Penny, Shelley Templeman, Madeline McKenzie, Daniela Tello Toral and Erin Hunt – State of the Tropics – 2020

[36] **State of the Tropics 2020 Report** – Sandra Harding, Ann Penny, Shelley Templeman, Madeline McKenzie, Daniela Tello Toral and Erin Hunt – State of the Tropics – 2020

[37] **Explore the Data** – State of the Tropics – https://www.jcu.edu.au/state-of-the-tropics/data – Accessed May 2021

Farmland: a Cornerstone

Fire has been essential for human existence since we emerged as a species some 300,000 years ago. Farming has been essential for our existence since we became reliant on it for our food, starting some 12,500 years ago. Fire and agriculture are the two cornerstones of human development.

Since the time of the first farmers, the Natufians, people have turned wilderness into farmland to address hunger and desperation. Today, hunger and desperation are concentrated in the Tropics. As a result, the expansion of farmland and the corresponding destruction of wildlife habitat are most pronounced in the Tropics.

Increasing agricultural yields is the most time proven means of increasing prosperity,[38] reducing hunger[39] and increasing the availability of land for wildlife.

Tanzania, the host country of the Serengeti National Park, provides a reference: Tanzania's main crop is corn[40] and the average corn yield in Tanzania is 1.5 metric tons per hectare (21 bushels per acre).[41] Although Tanzania has fertile land, its corn yield is low by international standards. The evolution of Tanzania's corn yield over the coming decades will be determinant for i) the future prosperity of the people of Tanzania who are currently 58 times poorer on average than Americans[42] and ii) the availability of wildlife habitat for the wild animals that live in that country.

Many of the risks that are widely perceived to be detrimental to wildlife – inclusive of global warming – are insignificant relative to the risk of habitat loss: The African elephant population has fallen by a factor of 20 times since 1930 because African elephants have lost

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[38] **Ending Extreme Poverty** – Interview of Ana Revenga by Amy Frykholm – 8 June 2016 – The World Bank (as first published by the Christian Century)
[39] **Ending Extreme Poverty** – Interview of Ana Revenga by Amy Frykholm – 8 June 2016 – The World Bank (as first published by the Christian Century)
[40] **The Maize Value Chain in Tanzania** – Food and Agricultural Organization of the United Nation – R. Trevor Wilson and J. Lewis – 2015
[41] **Tanzania, Grain and Feed Annual** – US Department of Agriculture – Ben Mtaki – 22 April 2020
[42] **GDP per Capita, 2019** – World Bank – https://data.worldbank.org – Accessed: November 2020

their habitat – their land – not because of global warming. Positively, when wildlands are recovered and given back to wildlife, wildlife populations recover. If Tanzania's corn yield was comparable to that of the United States (10.8 metric tons per hectare; 172 bushels per acre),[43] it would create an extraordinary amount of stomping room for African elephants. This is because only 12% of the land in Tanzania being used to grow corn would be required for that purpose. That would free 88% of the land currently being used to grow corn in Tanzania for other purposes, including providing wildlife with habitat.

But what does this have to do with the human use of fire?

Everything.

Fire has been instrumental in increasing agricultural yields from the Bronze Age to the present. This will be developed in the section "From Fire: Human Development".

The most important impact on wildlife resulting from the replacement of fire from burning coal, oil and natural gas with alternatives will relate to how that change affects agricultural yields. Whether we need more land to grow food, or less, is the factor that will determine whether wildlife thrives or perishes.

The frontier between farmland and wilderness represents the boundary between the wildfire regimes of nomadic and sedentary people. Having looked at farmland, the Agricultural Revolution and the importance of agricultural yields, let us now turn our attention to the technologies derived from fire.

[43] **Corn and soybean production up in 2020, USDA Reports** – US Department of Agriculture – 12 January 2021