EXTINCTIONS:
PAST AND PRESENT
UNIVERSITY OF CAPE TOWN

WEEK 4 THE EVOLUTION OF GRASSLANDS

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WB – William Bond

ACT It's a real pleasure for me to have with me today, William Bond. William Bond is an emeritus professor at the University of Cape Town and he's also a scientist at SAEON which a long-term ecological research centre. So, William, talking about changes in vegetation over time, you know, as a paleontologist, I've always been intrigued by these big changes that have happened after major extinction events. But grasses really take off much later. Do you have any idea what spurred the spread of grasses, grasslands much later?

WB Well, I think it's one of the most intriguing earth history mysteries but it's actually both the spread of flowering plants which is not, the reasons are not obvious, and then the second great angiosperm revolution. Well, there was another one as well, which is the spread of forests. The forests are also intriguing. And then these grasses, the most unlikely improbable growth form, a little plant, herbaceous plant half a metre to a metre tall that began to take over the world. So it was such an anomaly that, for many years, people thought, where you saw grasslands, especially the tropics, they were the consequence of human deforestation. People chopping trees down. And we know that that's now not true. They've been there for millions of years, although it's still a popular public belief that these grasses are secondary. They're not. They're ancient. So the big mystery is why did they take off? They were lurking around on the landscape. They were sitting, we think, in little edaphic soil ghettos, where forest trees couldn't grow and shade them out. And they hung in there by the fingernails until around eight million years ago, something changed and they just took off. And today they cover about a fifth of the world. So a remarkable change in global vegetation.

ACT So what could that something be?

WB Well, I think the important thing to say is that it's not climate because huge areas of grasslands and savannas have forests within that you can find on a hill, there's a forest and right next door, a savanna. So they're occurring under the same climate. And vast areas of savannas could be completely different. There could be forest. So this is unusual because, for many years, biogeographers have assumed that the major vegetation of the world is controlled by climate. Savannas, no. You need something to drive the forest back. And the first really coherent idea was, it was a drop in CO_2, atmospheric CO_2. And that this favoured a new form of grass, we call them C4 grasses. And their unique invention was to concentrate carbon dioxide in the atmosphere, so that, from the photosynthetic machinery's point of view, they were always operating at high CO_2. And this brought a whole lot of advantages, and disadvantages. It meant that the photosynthetic enzymes, which is the nitrogen that animals require, could be produced in much lower quantities. So from the animals' point of view you had a lot of carbon and hardly any protein and that reduced the quality. From fire perspective, this is the most wonderful fuel because the animals don't remove it, it's inedible and it's perfect fuel. So what we think is that, in large areas of the world, fires began to burn much more prominently and helped to promote the spread of savannas, rolling back forest trees. And the trouble with low CO_2 is that trees are intrinsically carbon-demanding, they have carbon-rich skeletons. So to build a tree you need a lot of CO_2. And when CO_2 plummeted... Our work, we did experimental studies on trees and their response to CO_2. They are hopeless at dealing with low CO_2, they can't handle drought, they can't handle browsing, they can't handle fire. So the low CO_2 provided the context, the necessary environment to weaken trees. But you needed that extra, something extra, to knock back the trees and WE think that was fire, and possibly herbivores.

ACT Uh-huh, and that brings me to your latest publication showing that, in the African savanna, it was actually a big role that bovids played in bringing grasslands to Africa and kind of cutting back on the forest. So that was very interesting.

WB Yeah, I'm very pleased with that paper.

ACT Well, you should be.

WB We struggle to put the animals into the picture. You don't get satellite maps of mammals. And what were dinosaurs up to in the Cretaceous? Clunking around and smashing trees, just walking down for a drink, they must have been smashing trees over. Now, how does one reconstruct that? So we did an analysis of plants that are restricted, trees that are restricted to fire-dependent savannas. To try and date the origin of savannas through dating the trees that grow within them. These were high-rainfall, fire-dependent savannas. But we knew that fire doesn't burn everywhere and that drier areas of Africa are still savannas but fires are much less common. And these are the centres of mammal abundance and diversity, the Serengeti, Kruger National Park, and so on. So we tried to find an indicator of mammal dominated savannas, and the big indicator, if you know anything about Africa, are prickly plants. If you walk around our big mammal reserves, they're full of prickly plants.

ACT Exactly.

WB So we took a sample of 2000 tree species from Africa, worked out how many were prickly, and we were able to reconstruct, for each tree, we could look at the environmental context, and where they grew, and see whether spiny plants are indeed markers of savannas, also markers of high animal density. That was a heroic effort, but nowadays people could do these things much more quickly. And we were helped by a wonderful piece of work by Gareth Hempson where he reconstructed the mammal diversity and abundance in Africa as it would have been a thousand years ago. Looking at data from game parks and national parks. And created a surface of mammal abundance and diversity, so we could then link where are the prickly plants and which mammals are feeding on them.

ACT Yes.

WB And that pointed clearly to the bovids and it pointed clearly to mixed feeders of medium-sized, social mixed feeders, like gazelles and impala and also large browsers, things like kudu. So, the sort of the goats and the deer of other parts of the world. So, now we knew that prickly plants were associated with grass, savannas, drier savannas on fertile soils. These were the epicentres of mammal abundance in Africa. And we knew which mammals, so now we went back in time using molecular phylogenies and, to our astonishment, we found that spiny plants were not an ancient feature of Africa. They were actually new, new in a geological sense, that, for tens of millions of years, Africa was full of proboscideans, elephants and their relatives, and hyracoids. Of which there are only a handful of little creatures left. But they were much bigger, they were the size of small rhinos in the past. With those browsers around, Africa had no spiny plants. And then spiny plants just, bam, act of creation and they just appeared in Africa and took off around 15, 16 million years ago according to our molecules. So then we looked at which animal groups, if any, coincided with the appearance of those spiny plants. And there were the bovids. Using the same approach with the bovids, there was this absolutely remarkable eruption of spiny plants and simultaneous eruption of bovids. Where did the bovids come from? Well, Africa had collided with Eurasia and, when the two continents met each other, the... began to get an exchange of Eurasian animals into Africa, and the elephants of Africa spread to the rest of the world, mammoths and mastodons and so on. But the legacy of those mammals, we argue, is intense. When the bovids arrive, there was intense herbivory on the seedlings and saplings of forest trees. And this helped to open up the forest, providing opportunities for the grasses...

ACT Grasses to take over, wow, that's fantastic. Quite a wonderful story.

WB It's an extraordinary thing and, of course, now we would like to know what is happening in other parts of the world. There were similar prickly forms of savanna in South America, in North America, in Asia. But they had older, or even younger, browsers so we can test the argument by looking at the world, you know.

ACT Exactly, looking at their fossil record and looking at the evolution of the mammalian fauna as well.

WB That's right.

ACT That sounds fantastic.

WB And we'll almost certainly be proved not completely right. But...

ACT Well, this is it. I think that’s the nature of science. We have a good hypothesis and we try to find evidence to support it and if it doesn't, well then we find another hypothesis.

WB Absolutely.

ACT So, William, given the high carbon dioxide concentration in the atmosphere currently, what do you think are the implications for the future?

WB Well, I like to walk around with a big placard saying, the end of savannas, the end of the world. I think we are really threatened with major loss of one of the world's great biomes, which contains, and it's not only high CO_2, it's a loss of the mammals that help to maintain these things as open. And it's suppression of fires, through roads, and buildings, and legislation. I think savannas have their backs to the wall, actually. And that's where the models are projecting, it's the future of Africa and African savannas looks pretty bleak.

ACT Really.

WB With all kinds of repercussions that we need to think about.

ACT So, William, thank you so much for coming and sharing your research ideas with us. And we look forward to hearing more from from your research group. Thank you.

WB No, it's a pleasure. I am an enthusiast, as you can see. And I reckon this is the most intriguing question that anyone could ask of earth history. Thanks.