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GUEST EDITORIAL

Four key areas for training the next-generation of global change researchers

Anthropogenic activities are changing the global environment in numerous ways, including increasing concentration of atmospheric carbon dioxide, alteration of biogeochemical cycles and changing land-cover types[1–3]. These changes are increasing stresses on ecosystem goods and services[4], driving climate change and thus creating a few grand challenges for sustainability of the human society[5]. Improving our understanding of these profound changes and grand challenges will help us in developing better predictive capabilities for the future. As these changes are expected to be long-lasting and we still do not have a complete understanding of their causes and consequences, the next generation of scientists needs to be properly trained in knowledge, methods and techniques in order to meet the research needs to tackle future challenges in global change ecology research. This guest editorial discusses the challenges and opportunities in preparing the next-generation global change researchers according to four key aspects of training.

First, the next generation of scientists must be trained in existing and new scientific approaches and methods from a multitude of disciplines (e.g. natural sciences, engineering and social sciences) and across a range of observational, analytical and computational techniques. The global change ecology is a highly interdisciplinary field which involves people, knowledge, techniques and data from a variety of disciplines[2,6]. Therefore, solving complex global change ecology problems requires knowledge from a range of disciplines working in interdisciplinary teams[7,8]. In the recent decades, new and improved techniques have been developed and adopted to address ecological problems through field experiments[9], numerical modelling[10], data assimilation[11], isotopic tracer methods[12], next-generation DNA sequencing method[13], molecular approaches, etc. These approaches provide improved ways to understand and untangle ecological complexities and thus help in observing, analysing and predicting global ecological change. A generation of scientists trained in these methods and techniques is needed to guide adaptation and mitigation of global ecological change in the 21st century. A workforce trained in interdisciplinary settings would also help increase success rates of large interdisciplinary research projects, which is a growing trend in current and future global change research.

Second, the next generation of scientists needs to be trained in data management and data analytics in the age of big data. Traditional ecology has not focused on generating huge volumes of data, but rather conducting studies at spatially focused locations for longer times. Data curation and archiving take a long time in traditional ecology which reduces data sharing, aggregation and synthesis activities, thus hindering investigations in larger spatial scales. With the emergence of large observatories, large-scale science projects producing very high resolution and complex datasets from *in situ* and automated sensors networks, ecology for studying global change is quickly turning into a big data science. Generation of high volume of complex data is changing the way ecological studies are being done and the focus is now more towards data integration, synthesis to ask larger-scale scientific questions. This paradigm is bringing in a drastic change in the field which holds a promise for better science in the future. The future global change researchers must be equipped with the skills necessary in handling these high volumes of complex data for data processing, data curation, data archiving and data analytics for synthesis and aggregation at local to global scale.

Third, the future generation of scientists must be able to address global change ecology problems working collaboratively and in international settings. The current changes in climate and ecosystem structure and function are happening at the global scale and at various degrees around different regions of the Earth. To have a comprehensive understanding of these changes, thorough and detailed studies of various issues involving researchers from different countries and varied backgrounds are needed. It is nearly impossible to conduct global-scale experimental studies due to various reasons, e.g. constraints in funding, logistics, permission to conduct research in another country, etc. Better representation of ecological understanding across different ecosystems is important in reducing the uncertainties in the global-scale model predictions. A synthesis of the understanding and knowledge gained from around the world can be accomplished through international collaboration and developing synthesis studies. Additionally, international scientific collaboration will also provide valuable opportunities to learn new scientific ideas and methods by connecting a global pool of researchers.

Fourth, future global change scientists must be equipped with strong communication skills and the ability to interact effectively with society, media and decision-makers. Among all the changes occurring as a result of global change, elevated atmospheric carbon dioxide concentration is best known. But the general public is still divided in comprehending the impacts of this key change. Therefore, there is a strong need to educate the public about the seriousness and consequences of such global ecological changes. The media can play a crucial role in this by conveying the right message to the public; therefore, the ability to communicate scientific knowledge to public audiences will be an essential skill for the future generation of global change scientists. Communicating the right message to decision-makers using the media and public engagement can generate necessary policymaking in supporting research in global change ecology field. All these factors make it essential that the next generation of researchers be trained in communication skills.

Emerging changes in the ecosystems around the world and the resulting challenges that they create call for an urgent task to train next-generation global change scientists as they prepare for a complex set of problems and solutions. The success of global change research depends, to a significant extent, on how well-prepared this next-generation workforce is. To maintain a sustained growth of the workforce in global change research, we need to better train the next generation of global change researchers in new and innovative observational techniques, big data and data analytics, collaborate across the many disciplines required to evaluate and solve global change problems, work in an international and interdisciplinary environment, and to be more effective in communicating the significance of ecological findings to the public and policy-makers. Recent efforts to generate a dialogue in this direction involved a mix of junior and senior global change scientists[14], where a consensus was reached that training next-generation researchers with the above-mentioned skills is essential in global change research. Education investment and research training must be emphasized to meet these needs.

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