

The dynamics of species change, pest status, and new pests on sugarcane in Indonesia

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Abstract. This review paper aims to determine whether there has been a change in the species and status of sugarcane pests over a certain period. This information is critical, especially for developing a pest management strategy for sugarcane in Indonesia. There have been changes in several species and pest status as well as the emergence of new pests on sugarcane. Changes in species, status, and the emergence of new pests on sugarcane are caused by shifting sugarcane planting land from rice fields to rainfed land, changes in cultivation practices, natural enemies, and climate change. Important pests on sugarcane during the three periods were top borer, stem borer, and white grubs.

1. Introduction

One of the main obstacles of sugarcane productivity in Indonesia is pest. In 1929, at least 131 species of insects have been reported attacked sugarcane, although not all were dangerous [4]. Conventional pest management was the main control method including quarantine to keep pests from entering Java (Indonesia), since 1890 [5].

Sugarcane cultivation has been established since the Dutch colonial period (1800's) with a lot of changes, from method of cultivation, varieties, and also environment or climate. These conditions, particularly the shift of sugarcane planting land from paddy fields to rain-fed land led to status change in pest species. Until now, the important pests of sugarcane in Indonesia are top borer (*Scirpophaga excerptalis* Walker), stem borer (*Chilo auricilius* Dudgeon, and *C. saccharipagus* Bojer) [6]. Borers were also the main pest in India [7], Pakistan [8], Iran [9], Ethiopia [10], Bangladesh [11], and Colombia [12].

Top borer caused severe losses, depend on the age of sugarcane, ie.: 77%, 58%, 46%, 24%, and 15% losses when the pest attack sugarcane plants at 5, 4, 3, 2, and 1 month before harvesting, respectively [13]. Other results showed that 60-80% of shoot borers attack decreased sucrose content at least 600 kg sucrose/ha [14]. In 2012, Asbani et al. reported that top borer caused losses ranging from 3-48 % depending on sugarcane varieties. The damage on PS 864 variety reached 3%, while PS 9460 variety reached 48% [15]

Stem borers attack every phase of sugarcane plant growth. Larvae entered sugarcane stalks which already has an internode. When the larvae made a tunnel in the inner stalk and caused 20% damage, the sucrose reduced by 10% [16]. While giant stem borer can cause more severe damage up to 60% [17], although in Medan, it only caused 5% damage [18].

Another important pest was white grub (*Lepidiota stigma*), which caused severe damage on sugar cane plantations in Java and Sumatra in 1995[19], and 70% damage in Takalar South Sulawesi and in Lampung [5]. White grubs usually attack sugarcane plant, especially when the crop is grown in sandy soil. The attack forced young plant (7-8 month old) to be cut down to avoid more severe white grub attacks [20].

This review study aims to determine the status change of sugarcane pest in Indonesia from Dutch period up to now. The pest list was divided into three periods based on the information obtained from the three main books [1,2,3]. This information is important for developing future sugarcane pest management strategies in Indonesia.

During sugarcane development in the Dutch colonial era was called as period 1. The sugarcane pest species and its status in Indonesia were recorded in the book "De plagen van de cultuurgewassen in Indonesie published in 1951, and then translated in English by Kalshoven in 1981 entitled "The pests of crops in Indonesia" [1]. In this period, sugarcane was grown in paddy fields which have very fertile soils under intensive labour cultivation system and irrigation. The cultivation system was named the Reynoso system and most of the sugarcane varieties planted are POJs varieties.

The second period based on pest list from the pocketbook published by ISRI/BSES/ACIAR written by [2]. In this period, the development of sugarcane shifted from paddy fields to rainfed areas and most sugarcane varieties planted were Ps and PS varieties. In this era was started from 1980s in which, sugarcane was grown under limited labour and less intensive. In 2017, the ratio between paddy field areas and rainfed areas was 22% : 78%.

The 3rd period based on Sugarcane Plant Pest Organisms guided by the Indonesian Sugar Research Institute published in 2017/18[3]. In this period, almost 80% (365.000 ha) of the total area of 445 000 hectares of sugarcane land is rainfed areas

The dynamics or changes in sugarcane pest species and status in Indonesia during the three periods are listed in Table 1. Each period can affect changes in pest species and status differently. Table 1 explains that there have been dynamics or changes in the species and status of every group of pests. They range from seeds and germination pests; root pests; top borers, stem borers, leaf destroyers, suckers, and big animal pests.

Tabel 1. Dynamics of sugarcane pest species and status in Indonesia within three periods

Pest group	Period		
	First	Second	Third
Seed and germination	Termite, <i>Macrotermes gilvus</i>	<i>Macrotermes</i> **	<i>Macrotermes</i>
	-	-	<i>Coptotermes</i> spp termites
	Mole crickets, <i>Gryllotalpa</i>	-	-
Root	Root bug <i>Stibaropus tabulatus</i>	-	Soil root bug <i>Stibaropus molginus</i>
	White grubs <i>Apogonia destructor</i>	-	-
	White grubs <i>Lepidiota stigma</i>	<i>Lepidiota stigma</i> ***	<i>Lepidiota stigma</i>
	White grubs <i>Leucopholis</i>	<i>Leucopholis rorida tibicens</i> *	<i>Leucopholis rorida</i>
	-	<i>Tibicens</i> *	Tenggeret <i>Tibiscens</i> sp
	<i>Phyllophaga</i>	<i>Holotrichia helleri</i> *	<i>Holotrichia helleri</i>
	-	<i>Euchlora viridis</i> *	<i>Euchlora viridis</i>
Top borer	<i>Tryporyza</i> (= <i>Scirpophaga</i>) <i>nivella</i>	<i>Scirpophaga excerptalis</i> ***	<i>Scirpophaga excerptalis</i>
Stem borer	<i>Chilo saccharipagus</i> Bojer	<i>Chilo saccharipagus</i> ***	<i>Chilo saccharipagus</i>

	<i>Pragmataecia</i>	<i>Pragmataecia castanea</i> ***	<i>Pragmataecia castanea</i>
	<i>Sesamia grisescens</i>	-	-
	Grey borer <i>Tetramoera schistaceana</i>	<i>Tetramoera schistaceana</i> *	Grey borer <i>Tetramoera schistaceana</i>
	-	<i>Chilo auricillius</i> ***	<i>Chilo auricillius</i>
	-	-	<i>Chilo terrenellus</i>
	-	-	<i>Pagenstecher</i>
	-	-	Sugarcane weevil borer <i>Rhabdoscelus obscurus</i>
	<i>Sesamia inferens</i>	<i>Sesamia inferens</i> *	<i>Sesamia inferens</i>
	<i>Chilo infuscatellus</i>	<i>Chilo infuscatellus</i> *	<i>Chilo infuscatellus</i>
	-	<i>Dorysthenes</i> sp.***	Boktor <i>Dorysthenes</i> sp.
	-	-	Rhino beetle <i>Oryctes rhinoceros</i> at the base of sugarcane stem
	-	-	Black beetle <i>Metanastes</i> sp. base of shoots
Leaf destroyer	Caterpillar <i>Cosmopteryx</i>	-	-
	Beetle <i>Asamangul</i>	-	-
	Grasshopper, <i>Valanga</i>	<i>Valanga nigricornis</i> *	Javanese grasshopper <i>Valanga nigricornis</i>
	Caterpillar <i>Agrotis</i>	-	-
	Caterpillar <i>Amsacta (Creatonotos) gangis</i>	-	-
	<i>Discophora</i>	-	-
	<i>Euproctis</i>	-	-
	<i>Melanitis</i>	-	-
	<i>Mocis</i>	-	-
	<i>Mythimna</i>	<i>Leucania (Mythimna loreyi)</i> *	Armyworm <i>Mythimna loreyi</i>
	-	-	Armyworm <i>Anticyra combusta</i>
	<i>Parnara barda (=philino)</i>	-	-
	<i>Pelopidas</i> spp.	-	-
	<i>Psalis (Dasychira) pennatula</i>	-	-
	<i>Spodoptera maurita</i>	-	Armyworm <i>Spodoptera</i> sp.
	<i>Thosea sijthoffi</i>	-	-
	<i>Hypomeces squamosus</i>	-	-
	-	<i>Locusta migratoria</i> ***	Migratory locust, <i>Locusta migratoria manilensis</i>
	-	<i>Antisyra combusta</i> **	-
	-	<i>Spodoptera litura</i> **	-
Suckers	Ladybug <i>Nezera</i>	-	-
	<i>Peregrinus</i>	-	-

	<i>Perkinsiella</i>	<i>Perkinsiella saccharicida</i> **	<i>Perkinsiella saccharicida</i>
	<i>Phaenacantha saccharicida</i>	-	-
	<i>Recilia dorsalis</i>	-	-
	<i>Thaia oryzivora</i>	-	-
	Aphids <i>Ceratovacuna</i>	<i>Ceratovacuna lanigera</i> ***	Sugarcane woolly aphid <i>Ceratovacuna lanigera</i>
	<i>Melanapsis</i>	-	Sugarcane aphids <i>Melanapsis sacchari</i>
	<i>Raphalosiphon</i>	-	-
	<i>Aleurolobus</i>	<i>Aleurolobus barodensis</i> *	Sugarcane whitefly <i>Aleurolobus barodensis</i>
	<i>Neomaskellia</i>	-	-
	<i>Scales Aulocaspis</i>	-	-
	<i>Odonaspis</i>	-	-
	<i>Saccharicoccus</i>	<i>Saccharicoccus sacchari</i> *	<i>Saccharicoccus sacchari</i>
	-	<i>Eumetopina flavipes</i> ***	-
	-	<i>Aulacaspis madiunensis</i> **	-
	-	-	Sugarcane scale insect <i>Aulacaspis madiunensis</i>
	-	-	<i>A. tagalensis</i> stem fluid sucker
	-	-	Sugarcane plant hopper <i>Pyrilla perpusilla</i> leaf sucker
	-	-	Leafhopper <i>Eumetopina flavipes</i>
	-	-	Sugarcane whitefly <i>Neomaskellia andropogonis</i>
Animals	<i>Rattus argentiventer</i>	<i>Rattus rattus argentiventer</i> ***	<i>Rattus rattus argentiventer</i>
	-	<i>Bandicota indica</i> **	<i>Bandicota indica</i>
	-	<i>Babyrousa babyrussa</i> *	<i>Babyrousa babyrussa</i>

Note: ***) very harmful pests **) harmful pests *) less harmful pests

1.1. Seed and germination pests

Termite (*Macrotermes* spp.) are seen in all periods (1, 2, and 3) with status as pests with moderate levels of damage. The data indicate that *Macrotermes* spp. survive in wet or dry lands. Currently, *Macrotermes* spp. are considered as pests that causing moderate levels of damage. In Nigeria, *Macrotermes* attacked both seedlings and stalks of sugarcane and caused 22-27% and by 8.6-16.7% respectively [22]; In Central Africa, the termites caused damage to sugarcane by 5-10% [23]; while in Chad (Central Africa) the termites caused 25% damage [24].

Mole cricket (*Gryllotalpa* sp.) was only found in the first period. The environment of paddy fields was more favourable for this pest compared to the conditions in rainfed areas. Currently, mole crickets are not recorded as damaging pest in sugarcane. According to Darwin, the cause of the dynamics is the ability of species to adapt to the environment and not the most robust species. *Gryllotalpa* sp. was also found as potato pest with losses up to 50% damage, both in Central and West Java [25].

1.2. Root pests

Root pest found only in the first period were: the root bug *Stibaropus tabulates* and white grubs *Apogonia destructor*, *Lepidiota stigma*, *Leucopholis* sp. and *Phyllophaga* sp. (= *Holotrichia helleri*) were three species of white grub found in all periods. *L. stigma* has been considered as an important pest in sugarcane, especially in sandy soil such as in Kediri, Tulungagung, Situbondo (East Java), and in Purworejo (Central Java) [20]. *H. helleri* is categorized as less dangerous pest. *Tibiscens* sp. and *E. viridis* were only recorded as pests in sugarcane in period 2 and 3.

1.3. Top borer

Tryporyza (= *Scirpophaga*) *nivella* was recorded as an essential pest in all periods [26][6]. This pest is the most serious pest in India, and reduced sugarcane production by 36-56% [27].

1.4. Stem borer

During period 1 the pests recorded were *Chilo saccharipagus*, *Pragmataecia*, *Sesamia grisescens*, grey borer *Tetramoera schistaceana*, *Sesamia inferens*, and *Chilo infuscatellus*. In period 2, there were additional species, namely *Chilo auricillius* and *Dorysthenes* sp. In period 3, there was an increase in the number of *Chilo terrenellus*, *Rhabdoscelus obscurus* sugarcane weevil borer, *Oryctes rhinoceros* rhino beetles which attacked the base of sugarcane plant stems, and black beetle *Metanastes* sp. which attacks the base of the shoot.

Boktor *Dorysthenes* sp. is a pest whose larvae attack the bottom of the stem in the ground and damage the rootstock. This pest was recorded in periods 2 and 3, wherein period 1, was not reported as a pest in sugarcane. Pramono et al. (2001)[28] reported that this new pest was first discovered in Subang, West Java, in 1999.

Adaptable species for three periods are *C. saccharipagus*, *Pragmataecia*, grey borers *T. schistaceana*, *S. inferens*, and *C. infuscatellus*. Until now, *C. saccharipagus* still has an essential pest status on sugarcane (Goebel et al. 2014 [29]; Subiyakto 2016 [6]). The other three species are minor pests. In period 2, there were two essential pest species, boktor *Dorysthenes* and *C. auricillius*. In period 3, there was an increase in the number of pests, from 7 to 11 pest species. Stem borer pests have become essential pests in various countries (Sallam. 2006) [30], including in Pakistan *C. infuscatellus* caused a 20-57% reduction in production (Ahmad et al. 2019) [31], and in Ethiopia, with an incidence of borers of 5-40% (Habebe et al. 2018).

1.5. Leaf destroying pests

For leaf-destroying pests, two pests can adapt in 3 periods, namely Javanese grasshopper *Valanga nigricornis* and armyworms *Mythimna*. Both have the status of mild pests. In period 2, *Locusta migratoria* pests were recorded as important pests, whereas previously, they were not recorded as pests. In period 1, there were many pest species recorded species, about 17 species, but in periods 2 and 3, the number of pests decreased to only 5. The pests are Javanese grasshopper *V. nigricornis*, *Mythimna loreyi*, *Anticyra combusta*, *Spodoptera* sp., and migratory locust *L. migratoria manilensis*.

Grasshopper pests constitute a significant threat to food security throughout the world. Attacking various continents except for Antarctica threatens the livelihoods of 10% of the world's population. These grasshoppers are famous for their agility, polyphagy, and capacity for long-distance migration (Latchininsky 2013) [32]. In Indonesia, grasshopper pest attacks (*L. migratoria*) are found in 25 districts in 8 provinces namely South Sumatra, Lampung, East Nusa Tenggara, West Nusa Tenggara, North Sulawesi, South Sulawesi, West Kalimantan and Central Kalimantan Provinces. Generally, there are two seasons in a year, namely, the April-September and October-March periods, and both have different broad patterns of locusts (Koesmaryono et al. 2005)[33].

Spodoptera frugiperda J.E. Smith, also known as fall armyworm (FAW), has been reported as a new pest attacking maize in Indonesia. The fall armyworm, *S. frugiperda*, is a crop pest native to the Americas, which has invaded and spread throughout sub-Saharan Africa within two years (Early et al. 2018)[34]. This pest has entered Indonesia and is found in Sumatra and Java. In West Java, fall

armyworms attacked maize in Bandung, Sumedang, and Garut Districts (Maharani et al., 2019) [35]. In addition to maize, fall armyworms attack many other economically important crops, e.g., rice, sugarcane, sorghum, beet, tomato, potato, cotton, and pasture grasses (Early et al. 2018)[34]. Although reported as a sugarcane host, there are currently no reports of fall armyworm attacking sugarcane in Indonesia.

1.6. Sucker

Pests that can survive in 3 periods are *Perkinsiella saccharicida*, sugarcane woolly aphid *Ceratovacuna lanigera*, sugarcane whitefly *Aleurolobus barodensis*, and *Saccharicoccus saccari*. For sucker pests, there is a change in the type of pest species where pests recorded in period 1 were not recorded as pests in period 2 or 3. There is a change in pest species and the status of sucker pests for three periods. In 1996 *Ceratovacuna* was an essential pest in sugar cane in Indonesia (Suhartawan, 1998)[36]. *P. saccharicida* Kirkaldy is not only a pest but also a vector of sugarcane virus disease (Vercambre, 2010)[37]. *C. lanigera* Zehnter is an important pest of sugarcane in many parts of India, including Maharashtra and Karnataka (Patil & Chavan. 2009)[38]. Whitefly *A. barodensis* in various Indian states causes a decline in sugarcane production by up to 24% (Bhavani & Rao, 2013)[39]. In Egypt, the *S. saccari* attack affected sugarcane's physical and chemical properties (El-Dein et al. 2009)[40].

1.7. Big Animal

Animal species that damage sugarcane plants and are able to survive in 3 periods are rat *Rattus rattus argentiventer*, which has been recorded as important pests until now. In period 2, there were additional pests, namely greater bandicoot rat, *Bandicota indica* with pest status as medium destroyers, and pigs, *Babyrussa babyrussa*, where previously both species were not recorded as pests. Until period 3, the two animals were still recorded as pests.

In Indonesia, *R. argentiventer* rodents can cause re-planting when attacking young sugarcane. Rodents attacking old sugarcane cause a decrease in sugar cane weight of 20-50% and reduce the yield to 48% (Achadian et al. 2011)[2]. In Ethiopia, rodents cause sugar cane damage by around 4% (Takele et al. 2008)[41]. In Australia, rodents cause damage to sugarcane ranging from 2 - 5%, in Hawaii can reach 40%, South America 12-20%, and in India, 20.7% (Takele et al. 2008)[41].

1.8. New pests

Based on the results of a survey funded by the Australian Center for International Agricultural Research (ACIAR), there are several new pests of insects on sugarcane that need to be aware. Soil bedbugs (*Stiboropus moginus*), cicadas (*Tibiscen* sp.), lack beetles (*Metanestes* sp.), horn beetles (*Oryctes rhinoceros*), and sugar cane borer (*Rhabdoscelus obscurus*). The insect pest population is found in several regions in Indonesia with a low population level, but its presence needs to be aware (ACIAR 2016)[42]. However, based on Table 1, some of the new pests on sugarcane are *Coptotermes* spp termites, *Chilo terrenellus*, *Pagenstecher*, sugarcane weevil borer *Rhabdoscelus obscurus*, rhino beetle *Oryctes rhinoceros*, black beetle *Metanestes* sp. base of shoots, armyworm *Anticyra combusta*, sugarcane scale insect *Aulacaspis madiunensis*, *A. tagalensis* stem fluid sucker, sugarcane plant hopper *Pyrilla perpusilla* leaf sucker, leafhopper *Eumetophina flavipes*, and sugarcane whitefly *Neomaskellia andropogonis* leaf sucker.

2. Discussion

Environmental changes caused the occurrence of pest type and status dynamics in Indonesia sugar cane plants. The shift in sugar cane development from rice fields ecosystem to rainfed land, changes in cultivation techniques, changes in planting from plant cane to a repetitive ratoon cane, unwise use of chemicals (pesticides and fertilizers), sugarcane varieties shifting or introduction, as well as climate change, are essential factors causing dynamics. Besides, it is caused by changes in personal views,

including better demands on agricultural products, assessment of pest status, and advances in taxonomy/pest identification.

Changes in the ecosystem of paddy fields to rainfed can impact certain types of insect adaptability which live on the ground. For example, soil insects and mole crickets *Gryllotalpa* sp. can adapt to the paddy field ecosystem but cannot adapt in dry or rainfed ecosystems. So that mole crickets are not found in rainfed sugarcane development areas (in Periods 2 and 3). However, some other pests, such as white grubs, can adapt to the paddy field and rainfed ecosystems. Insects that survive on sugarcane are insects that can use sugarcane as a host plant and can improve the condition of their environment (Pamberton & Williams 1969)[43].

Insects that live in plantations, such as borers, with a change in ecosystems from paddy fields to rainfed land, have no significant changes. The number of borers recorded is increasing, where in period 1, there were seven species, and in period 3, there were 12 species. Around 16 species of leaf-destroying pests were recorded in period one and decreased to 5 species in period 3. Overall, the insect species decreased from 47 species in period 1 to 27 in period two and increased to 37 species in period 3. Animal pests recorded increased from 1 species, rat *R. argentiventer*, in period 1, and there were two additional species in periods 2 and 3, namely Greater bandicoot rat *B. indica* and pigs, *B. babyrussa*.

The presence of natural enemies also determines the dynamics. Such as Jatiroto flies *Diatraeophaga stiatalis* Townsend, which can reduce stem borer attacks from 18% to 6%. The release of *Trichogramma* parasitoid also affects the stem borer population. The other natural enemies, such as *Encarsia flavoscutellum* Zehntner parasite, often found in young flea eggs, were 6-10 parasites produced by fleas in an 8-10 days cycle. The parasite can protect against *Chillocorus* spp. and *Scymnus* sp. (Kalshoven 1981)[1].

Tanwar & Varma (2001)[44] reported that *C. flavipes* Cameron (Hymenoptera: Braconidae) is an essential gregarious larval endoparasitoid of sugarcane borers. It is widely distributed in different growing regions in India, with a range of parasitization from 4.0 to 21.6 %. Padmasri & Sudh Rani (2014)[45] reported that in India that the average intensity of inter-node shoot damage and borer damage decreased to 70.70 and 53.87 % in 2011 and 2012, respectively, and the average percentage incidence of inter-node shoot damage and borer damage decreased to 64.92 and 49.66 % in 2011 and 2012 respectively.

Changes in the fertilizer used could also cause pest species and status dynamics. In 1963 single fertilizer was used with a dose of 80 kg Nitrogen, 40 kg Phosphate, and 120 kg Potassium per hectare for sugarcane development in paddy fields and fertile land. In 1980, single fertilizers were used in paddy fields on ratoon cane (RC) with fertilizer dosages of 80-120 kg N, 40-90 kg P₂O₅, and 60-180 kg K₂O per hectare. In rainfed areas, ratoon plants use fertilizer doses of 130-150 kg N, 40-90 kg P₂O₅, and 60-180 kg K₂O per hectare. From the aspect of pest biology, nitrogen fertilizer addition increases amino acids and protein. Its influence on pest biology accelerates the life cycle of pests and the development of pest populations (Veromann et al., 2013)[46].

Varieties changes can cause changes or dynamics of pest species and status. From 1931-1989 the varieties of sugarcane planted were POJ, which has relatively soft stem properties. The varieties planted in 1987-1990 were Ps 1 and Ps 61 varieties that have relatively tough stem properties. In 1990 the varieties were planted PS sugar cane with tough stem properties. In 2004, the varieties planted were mostly Bululawang varieties. This variety is suitable to be developed in coarse-textured soil (loam soil) and fine-textured with good drainage. This variety is sensitive to shoot and stem borer. In 2014, almost 80% of sugar cane farmers in East Java planted Bululawang varieties, of which around 86% were ratoon plants. From the pest control aspect, the dominance of certain varieties and the repeated planting of ratoon cane (RC) trigger more severe pest attacks.

The dynamics of pest species and status can also be affected by the occurrence of climate change (Cardozo et al., 2013) [47]. Kumar et al. (2018)[27] reported a correlation between *C. infuscatellus* population and various environmental factors, revealing a significant positive correlation with maximum temperature and a non-significant and positive correlation with minimum temperature.

Until now, there has been no comprehensive research on climate change on pests and disease development in Indonesia.

Events in the field give a definite indicator that there is a close link between climate change with pests and disease problems. Increased air and CO₂ temperatures have a direct and indirect effect on insects. Direct influences on insects include reproduction changes, life force, spread, behavior, and physiology. The increase in CO₂ causes a decrease in nitrogen in the leaves and can increase insect consume leaves by up to 40% to compensate for insects needs for nitrogen. On the other hand, an increase in CO₂ reduces plant resistance to insect pests (Belskaya & Vorobeichik 2013)[48].

3. Conclusion

There has been a shift in several species and pest status, as well as the emergence of 12 new pests on Indonesia sugarcane. There were 16 species of pests able to adapt for three periods recorded with status as pests that are very harmful to less harmful. These species of pests include pests that attack seeds and germination, pests that attack roots, shoot borers, stem borers, giant stem borers, and grey borer pests. The recorded species that can adapt in three periods as leaf destroyers, exploiters, and pests are animals. Changes in species, pest status, and the emergence of new pests on sugarcane are caused by shifting sugarcane planting land from paddy fields to rainfed land, changes in cultivation practices, for example, the types and doses of fertilizers, varieties, plant cane/ratoon cane, natural enemies, pest control practices and climate change.

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