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Mapping Access and Use of Weather and Climate Information to Aid Farm Decisions in the Philippines

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A reliable farm decision model is becoming increasingly important, particularly in countries highly vulnerable to adverse climate change impacts. In this paper, social network analysis and ethnographic information were combined to map weather and climate information networks of rice and corn farmers in Oriental Mindoro, Philippines. Snowball sampling generated the network data locating the otherwise hidden population. Most of the respondents source their information from television. The topmost information that is accessible and used by rice farmers is on tropical cyclones, while corn farmers seek information about the wet and dry seasons. Despite the seemingly autonomous decision-making among farmers, there are nodal farmers in the networks whose reach can potentially influence their peers and improve the delivery of weather and climate information. These identified farmers either occupy a local leadership position or are members of farmers' organizations. Predominantly, they have been farming for at least 25 years. These farmers can serve as 'bridges' to other farmers who are isolated or peripheral in the network by connecting them to the core's primary contacts. Capacitating these potentially influential farmers could further improve the flow of weather and climate information, and better serve the farmers beyond the reach of agricultural extension services. Moreover, farmers' experience of precarity, pressures them to take risks despite unfavorable forecasts and advisories. Climate studies and farm decision modeling should not leave out these narratives on agricultural precarities to understand the complexity of the effects of climate variability in agriculture.

Keywords: agricultural extension, farm decisions, farmers, social network, weather and climate information

Abbreviations: ACIAR- Australian Centre for International Agricultural Research, CSU- Charles Sturt University, NSIC-National Seed Industry Council, NIA- National Irrigation Authority, MAO- Municipal Agriculture Office, PAGASA-Philippine Atmospheric Geophysical and Astronomical Service Administration, PHB- Pioneer Hi-Bred, PIDS-Philippine Institute for Development Studies, SARDI- South Australian Research and Development Institute, SNA-Social Network Analysis, and W&C- Weather and Climate

INTRODUCTION

The Philippines is one of the countries that is most vulnerable to the impacts of climate change and climate-related hazards, such as extreme drought, typhoons, rainfall-induced flooding, and landslides. With the frequent occurrence and intensity of these extreme events, the consequences are costly. Large amounts of funding for relief and rehabilitation of damages have become essential in post-disaster responses (Comiso et al. 2014). By 2050, the estimated cost of the impacts of climate change and variability to the Philippine economy could be as much as PhP 26 billion (USD 518 million) annually (Dikitanan et al. 2017).

Smallholder farmers in the Philippines are among the groups that are vulnerable to the impacts of climate change and variability (Pulhin et al. 2016). When Typhoon *Haiyan* (locally known as *Yolanda*) made landfall in 2013, more than 6,000 lives were claimed and a total of PhP 571.1 billion (USD 12.9 billion) worth of damage to infrastructure and agriculture occurred in an instant of time, impeding economic growth by about 0.9% and 0.3% in 2013 and 2014, respectively (World Bank 2017). It was one of the most devastating events for more than 230,000 farming and fishing families, who needed an emergency response and livelihood rehabilitation from the government and other agencies (FAO 2017). Philippine government policies have been adopting several frameworks that would address climate change vulnerability, including resilience building, harmonized climate change adaptation and disaster risk reduction, and climate-resilient agriculture. However, one of the limitations of implementation is the need to upgrade the delivery of weather and climate (W&C) information from the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA), the government agency responsible for producing and managing weather and climate data to various vulnerable sectors, including smallholder farmers (UNISDR 2013).

Improving the delivery of W&C information can aid smallholder farmers in farm decision-making to reduce their risks and become climate resilient (Nkiaka et al. 2019). Skillful climate forecasts and advisories would reduce climatic uncertainties (Hansen et al. 2004). While institutional sources of W&C information are useful, many farmers also rely on their local knowledge and personal experiences from years of farming or consult their social network for information (Pratiwi and Suzuki 2017). In the case of the Philippines, many smallholder farmers depend on their social networks across the different stages of farming from land preparation to marketing. Informal social networks of kinship, friends, neighbors, laborers, sources of credit, and others are more likely to be used by farmers than formal pathways of information from the government (Pratiwi and Suzuki 2017; Lyon 2000).

Farmers facing climate-related challenges are sharing information and adopting agricultural technologies they deem appropriate. Farms have different production characteristics and farmers have different knowledge and experiences. They interact and learn from other farmers in times of uncertainty. These interactions are supported by social networks of information and adaptation strategies that contribute to the resilience of farmers (van Duinen et al. 2012). Hence, assessing the social networks of farmers can determine how information flows through many actors and thereby lead to an understanding of the role of these actors in their communication process (Othieno et al. 2014).

This study uses social network analysis (SNA) and rapid ethnographic assessment to assess how rice and corn farmers in selected sites in Oriental Mindoro, Philippines access and use different types of weather and climate information. It generally aims to understand the role of social networks in the delivery of W&C information among smallholder farmers. We investigate first the types of weather and climate information that are important to the farmers, and second, the dynamics by which this information is received and used by them. The paper also includes non-farmer actors connected in the network who might influence farmers' access and use of W&C information.

Background

Around 11 million Filipinos (27% of the country's total employment), especially in rural and upland areas, are involved in agriculture as their main source of income (FAO 2018). Either through subsistence or commercial farming, the reliance on agriculture is crucial in the nation's economy. However, due to the impacts of climate change and climate variability, the government estimates that more than 6 million hectares of crops were damaged between 2006 and 2013 from typhoons and severe storms, resulting in a total loss of USD 3.8 billion (UNDP 2019). In 2019, Oriental Mindoro was placed under a state of calamity due to the devastating landfall of tropical storm *Kamuri* (locally known as *Tisoy*). Of the overall damages to crops, infrastructure, and properties (PhP 384M or USD 7.6M), 78% (PhP 300M or USD 5.9M) were damages to the agriculture sector alone (Virola 2019).

Farmers are acutely aware of these impacts and are constantly adapting to climate change and variability since their livelihoods are at stake. Although there has been increasing support to upgrade the services of PAGASA, it was only in 2004 that there was a paradigm shift to disaster management in the Philippines from 'relief and response' to 'preparedness and mitigation' (SEPO 2017). The high-level awareness was triggered by a series of tropical cyclones that resulted in massive landslides and floods in various regions of the country (SEPO 2017). The outcome was the recognition of the importance of using weather and climate-related information to reduce the risks to agriculture (Hansen et al. 2004). Even though there is a considerable volume of weather and climate information available for farmers, the challenge lies in linking this information to a wide range of farming decisions (Stone and Meinke 2006). Access to reliable knowledge and information across the value chain is needed by farmers to improve their productivity (Aidoo and Freeman 2016).

Farmers rely on information shared within their informal social network especially when there is no means to get agricultural information from formal sources (Pratiwi and Suzuki 2017; Boahene et al. 1999; Lyon 2000). Behind every interaction is a flow of ideas, knowledge, and information that shapes their decisions in farming production and adaptation despite the challenges imposed by climate variability (Ramirez 2013). Many previous studies have emphasized the potential of interpersonal communication networks to enhance climate adaptation strategies. For instance, farmers usually obtain the agricultural information they need from their friends, neighbors, and relatives, who are readily available and accessible to them (Aidoo and Freeman 2016; Licht and Martin 2007; Lwoga et al. 2011; Okwu and Daudu 2011). Even in communities where social organization and infrastructure exist, farmers opt to consult their co-farmers as their key information source (Aidoo and Freeman 2016; Demiryurek et al. 2008). Local farmers who are also opinion leaders are reliable sources of new information and advice (Aidoo and Freeman 2016; Rogers 2003). In the extension study conducted by Ssemakula and Mutimba (2011) in Uganda, it was revealed that a high level of communication between farmers existed in contrast to when farmers communicated with extension service providers.

MATERIALS AND METHODS

Study Site

The study was carried out in Barangay Biga in Calapan City and in Barangay Narra in Gloria on the island province of Oriental Mindoro, Philippines (Figure 1). The province is one of the main islands in the country comprising 1.5% of the Philippines's total land area (436,472 ha). Agriculture and fishing are the major economic activities and sources of income in Oriental Mindoro (PSA 2018). Calapan City, the provincial capital, has a total land area of 25,006 ha. Its landscape is characterized by vast irrigated rice plains with mountainous areas, such as the prominent Mt. Halcon, which serve as the sources of water of downstream rivers, streams, and irrigation canals. The coastal municipality of Gloria, on the other hand, is located in the southern part of Oriental Mindoro with a total land area of 24,552 ha. The municipality is consisting of lowland and upland areas with rainwater as the main source of water for growing corn.

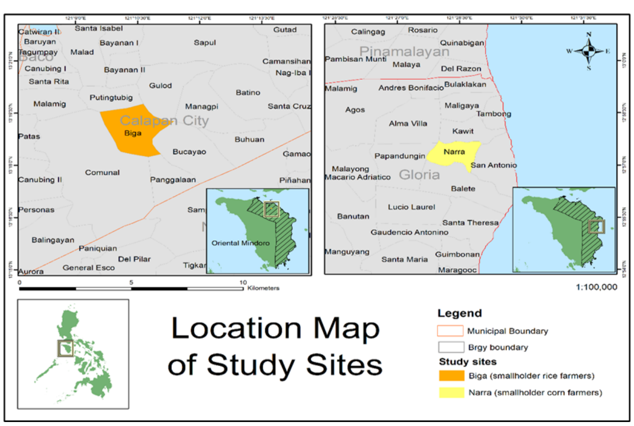

Fig. 1. Location of the study.

According to the Coronas climate classification of PAGASA, Oriental Mindoro has a Type III climate. This climate type has no pronounced maximum rain period but has a short dry season lasting from one to three months. With this climate type, the study areas are shielded from the Northeast Monsoon (*Amihan*) but are exposed to the Southwest Monsoon (*Habagat*). The region also gets rainfall from an average of 20 tropical cyclones that pass through the country every year. Type III climate intermediates between Types I and II, although it is more similar to Type I due to its short dry season (De Alban 2010).

Data Collection

Data collection was done in three main stages, an initial site visit, a rapid ethnographic assessment, and a social network survey. An initial site visit was conducted to visualize the landscape, interview key informants, and determine the network boundary. During the initial site visit and interviews, there was a hidden farmer population (other farmers, laborers, tenants) in the access networks that were not on the master list of the Municipal Agriculture Office (MAO). These included those who were non-residents of the barangay but whose farm was within the barangay. Although they do not reside in the barangay where their farm is located, some farmers tend to share information in the same/nearby fields in the barangay. These individual nodes in the barangay can only be captured through the snowball sampling approach.

After identifying the boundary of the network, the second stage determined the farmers' local classification of weather and climate conditions to inform the design of the social network survey. A rapid ethnographic assessment was used to elicit information about the different types of weather and climate conditions perceived and used by rice and corn farmers. This assessment method is typically applied in the field of ethnoscience such as in ethnobiological (Lima et al. 2016) and ethnogeological (Garcia et al. 2020) studies and for knowledge co-production (Roue and Nakashima 2018). In this study, the local classification of the weather and climate conditions was treated as a cultural domain. Cultural domains are about the farmers' cognitive understanding of how things should be organized rather than their preferences (Bernard and Gravelee 2015). A cultural or semantic domain is a set of related items, themes, concepts, or statements on a single topic; in this case, the types of weather and climate conditions experienced by farmers. Cultural domain workshops were conducted with 10 rice farmer leaders in Barangay Biga, Calapan City and six corn farmer leaders in

Barangay Narra, Gloria on July 4 and 5, 2019, respectively. The workshop data were further supplemented with information from participant observation during September-October 2019 and February 2020. Ethnographic data help explain how the structure of the access network is being used by farmers to inform them in their decision-making. The types of weather and climate conditions enumerated by rice and corn farmers during the workshops (Table 1) were summarized and used as basis for the social network survey to derive the relations between farmers regarding the flow of W&C information.

The third stage was the implementation of the social network survey. The mapping and measuring of relationships describing information flows between and among actors, or any other type of relations, is called social network analysis (SNA). The SNA survey used snowball sampling, a non-probability sampling technique based on referrals, where a small number of people with certain attributes recruit others with similar attributed from their networks or community (Valerio et al 2016). Members of the network included farmers, extension workers, television, radio, and the moon calendar. The network population, 261 in Biga and 160 in Narra, was derived from responses of 260 individuals (irrigated rice farmers) in Biga and 156 individuals (83 rainfed corn farmers, 36 rice farmers, 35 vegetable farmers, 1 extension worker, and 1 government worker) from Narra. Data collection was limited by the availability and accessibility of the referrals mentioned. Some referrals in the network were disregarded due to their time unavailability or refusal to be interviewed. Moreover, referrals who were situated far off from the barangay were not pursued, given the limited time and unfamiliarity of their addresses or locations.

The respondents in the first stage, also known as the focal nodes of the network, determine who the respondents will be in the following stages (their sources and recipients of weather and climate information). The referrals were surveyed in a similar way as to how the focal nodes were asked.

Data Analysis

The measurements that SNA provides capture various roles in a network such as the connectors, leaders, bridges, isolates, clusters, the core and the periphery. The software package UCINET version 6.653 (Borgatti 2002) was used to visualize the network and generate the network metrics in this study. Classic SNA metrics were calculated to determine the potentially influential nodes, namely, degree centrality, betweenness centrality, and network density. Table 2 summarizes the most common, yet important network and node metrics used in this research.

Linkages that only include people were further explored to identify influentially positioned rice and corn farmers. Influence is measured based on the node's indegree, outdegree, and betweenness centrality for each important type of weather and climate information and comparing this influence with the measures in the whole network of Biga and Narra.

Table 1. Types of weather and climate information.

Rank	Weather and Climate Information
1	Typhoon warning (Babala sa bagyo)
2	*El Niño* advisory *(Abiso sa El Niño)*
3	*La Niña* advisory *(Abiso sa La Niña)*
4	Flood warning (*Babala sa pag baha)*
5	Rainfall forecast (*i.e pabugso-bugsong ulan, panakanakang ulan, ulang mayaman, ambon)*
6	Wet season (*Tag-ulan)*
7	Thunderstorm (*kulog at kidlat)*
8	Relative humidity (*i.e maalinsangan, maalingahot)*
9	Wind (*i.e Amihan, Habagat)*
10	Dry season (*Tag-init)*
11	Drought *(Tag tuyot)*
12	Subasko (*Squall)*
	(Local and traditional knowledge)
13	Indications of rainfall *(Indikasyon na uulan na)*
14	Onset of rainy season (*Pag simula ng tag-ulan)*
15	Onset of dry season (*Pag simula ng tag-init)*
16	Onset of drought (*Pag simula ng tag-tuyot)*
17	Knowledge about 'Maria Loka' (*Kaalaman tungkol sa 'Maria Loka')*
18	Others

Table 2. SNA network metrices.

Centrality Measures	Description
Node-level metrics	
Degree Centrality	A type of node-level metric that measures the number of direct connections a node has. Commonly used as a measure for the number of links coming to a person (indegree) and from a person (outdegree). Moreover, it anchors on the idea that nodes with the greatest number of ties to other nodes in the graph are considered 'important nodes' (Poudel et al. 2015).
Betweenness Centrality	Another node-level metric that indicates bridging. It refers to those individuals in a network who occupy strategic position and serve as a link to others. Having bridges is important in a network in terms of linking with other disconnected or distant groups (De Brún and McAuliffe 2018).
Network-level metrics	
Density	Density is a type of network-level metric that is calculated by dividing the number of ties in the network by the total number of potential ties (De Brún and McAuliffe, 2018). 'Potential ties' is a connection that could potentially exist between two persons or nodes, regardless of whether they actually have it or not (Hanneman and Riddle, 2014). It represents network cohesiveness.

RESULTS AND DISCUSSION

This section integrates the results and findings elicited from both the qualitative and quantitative methods. The network population is first described in terms of the farming characteristics of its members. Access to the different types of W&C information is discussed into three subsections, namely, to identify the sources of important W&C information; to describe the whole networks, particularly its density, core-periphery relations, and to corroborate on the findings about which W&C information are important; and to investigate on the potential of presently positioned influential farmers in bringing access to peripheral and isolated members of the network. Lastly, answers the study's objective to assess how farmers use the W&C information available to them, including their own generational experience and those sourced from the social network.

Farming Characteristics of the Network Population

The population in the weather and climate information network in the study areas is predominantly male; 81% among rice farmers in Barangay Biga in Calapan City and 70% among corn farmers in Barangay Narra in Gloria, with an average age of 52 and 53 years, respectively. Rice farmers in Barangay Biga can be categorized into four types: traskuhan or tenants (57%), lessees (7%), farm owners (29%), or farm laborers (4%). On the other hand, the network population in Barangay Narra consists of corn farmers who own their land (32%), farm laborers (3%), tenants (26%), *ariendo* or farmers who lease their lands (37%), and one agricultural extension worker from the municipal government. Rice (76%) and corn farmers (79%) in the network belong to farmer organizations that are formed at the barangay level and recognized by the City/Municipal Agriculture Office (Table 3).

While most rice farmers are male, the average years of farming are higher among female rice farmers (40 years) compared to male rice farmers (33 years). Most of the corn farmers in Barangay Narra have been farming for less than 20 years with a 19-year average among males and a 16-year average among females. Farming knowledge for both rice and corn are learned from personal experiences or passed on from older generations of farmers in the family. Formal higher education is not seen as a prerequisite in farming as reflected in the educational attainment of the farmers wherein many are elementary graduates (45% and 37% in Biga and Narra, respectively). In terms of water supply, rice farmers (90%) in Biga source their water from the irrigation system of the National Irrigation Authority (NIA); the remaining 10% use a water pump. Corn farmers in Gloria heavily rely on rainwater to grow their crops (94%) with the minority (6%) using a water pump or a solar pump (Table 3).

Inbred or open-pollinated varieties of rice and corn are preferred by the farmers in Barangay Biga (76%) and Barangay Narra (78%). Not more than 25% of the farmers in the networks plant hybrid varieties (Table 3). The specific inbred varieties grown by most rice farmers are Dinorado, NSIC Rc 218 (Mabango 3), NSIC Rc 300 (Tubigan 24), and PSB Rc18 (Ala). The hybrid varieties are PHB (Pioneer Hi-Bred) 73 of the DuPont Pioneer

Table 3. Summary profile of the respondents.

Farm Profile	Biga, Calapan (Rice) (N=260)	Narra, Gloria (Corn) (N=155)
Sex		
Female	50 (19%)	46 (30%)
Male	210 (81%)	109 (70%)
Ave. Age	53 yrs. old	52 yrs.old
Educ. Attainment		
Elementary	118 (45%)	58 (37%)
Highschool	41 (16%)	35 (23%)
College	15 (6%)	(7) 5%
Tenure status		
Owner	75 (29%)	41 (32%)
Tenant	148 (57%)	40 (26%)
*Lessee**	18 (7%)	58 (37%)
Trader	-	-
Laborer	10 (4%)	5 (3%)
Extension worker	-	1 (1%)
*Others***	9 (3%)	2 (1%)
Farming experience (Ave.)		
Male	33 years	19 years
Female	40 years	16 years
Farmer Org. membership		
Member	197 (76%)	123 (79%)
Non-member	63 (24%)	32 (21%)
Main source of water		
Rainfed	-	145 (94%)
Irrigation	235 (90%)	-
Small water impounding	-	-
Shallow tube well	-	-
*Others****	25 (10%)	10 (6%)
Crop variety		
Inbred (OPV)	197 (76%)	102 (78%)
Hybrid	60 (23%)	47 (22%)
Certified	3 (1%)	-
Others	-	-
Ave. Land Area	2.5 ha	1.5 ha
2018 Ave. Annual Household Income		
PhP 40,000 and below	79 (30%)	105 (68%)
PhP 41,000 - PhP 59,999	47 (18%)	21 (14%)
PhP 60,000 - PhP 99,999	67 (26%)	14 (9%)
PhP 100,000 - PhP 249,999	53 (20%)	7 (5%)
PhP 250,000 and above	6%	8 (5%)

company, Bigante Plus of the Bayer Crop Science company and Mestiso from the Philippine Rice Research Institute. Most corn farmers grow Lagkitan or Glutinous Composite #2 and the Yellow OPV developed by the Institute of Plant Breeding at the University of the Philippines Los Baños. The hybrid corn varieties are Yellow Corn Hybrid and White Corn Hybrid of Pioneer Hi-bred Philippines and Syngenta Philippines.

With the farmers' preference for low-yielding inbred varieties over hybrid varieties, and an average farmland of 2.5 hectares and 1.5 hectares for Biga and Narra, respectively, the annual household income in 2018 of 30% of the rice farmers in Barangay Biga and 68% of corn farmers in Narra is below PhP 40,000 (USD 791.68). There are also farming households in Barangay Biga (3%) and Barangay Narra (13%) that are below the poverty threshold per capita for the province of Oriental Mindoro, that is, PhP 12,032 (USD 238.14) (PSA 2018) (Table 3).

Sources of Important Weather and Climate Information

Farmers know that agricultural activities are sensitive to climate and weather conditions. Thus, climatological data or agroclimatic information are important in any farm decision-making. Decisions regarding land use and management, plant, and animal breed selection, and crop production practices, such as irrigation, as well as pest and disease control, must not be made without knowing the expected weather and climate conditions (WMO 2012). Agricultural practices such as sowing, fertilizer application, plowing, etc. are done at particular times, depending on when the weather conditions are expected to be most favorable. Real-time agroclimatic information can, therefore, aid farmers in adjusting their expectations and optimizing their decisions.

Rice and corn farmers do not have access to all the weather and climate information provided by PAGASA, the national government's weather bureau. This is partly due to the exclusive accessibility of the online platform and the familiarity of the farmers with the impacts of limited weather and climate events, resulting in preferences for certain types of W&C information. When farmers do rely on W&C information from the formal information pathways of PAGASA, they seek what they consider important W&C information to avoid its negative impacts.

In Biga, the most accessed and used information types for rice farmers, based on the percentage of the respondents who mentioned the information, were tropical cyclone (94%), rainfall forecast (24%), wet season (11%), and dry season (5%). The results in Narra showed that information about the wet season was the most (72%) accessed and used information, followed by dry season information (54%).

Out of the 260 rice farmers interviewed in Biga, 250 stated that television was their main source of the different types of weather and climate information. It was followed by Android phones (4) and then radio (3). Only two respondents stated that they obtained information from other farmers who happen to also be their neighbors. In contrast to rice farmers, corn farmers have relatively more diverse sources of information. The major source of information in Narra was also television (63%), but 14% of the respondents indicated that they obtained information from a local farmer leader, while 12% received it from their relatives. Furthermore, 3% also obtained information from their co-farmers. One farmer respondent sourced weather and climate information from the local extension officer assigned in Narra. The survey indicates that there are a few farmers (3%) who traditionally rely on the moon calendar to guide them in their planting schedule. Farmers correlate the phases of the moon to favorable and unfavorable weather conditions for planting and harvesting. Only one farmer was able to access the internet to check weather forecasts. During the interviews, some farmers did not state their sources of information because they claimed to have stopped believing and relying on forecasts due to their inaccuracies. They rely instead on their personal experience to guide them in farming.

Most of the rice and corn farmers in the study sites depend on network television to get information about the path, intensity, and arrival of tropical cyclones, as well as forecasts for the wet and the dry seasons. Presently, these are the types of weather and climate information that farmers deem the most important for them to receive on time.

Weather and Climate Information Networks

The previous section revealed that not all types of weather and climate information are equally important to rice and corn farmers, and thus, not all are being actively sourced. The importance of the W&C information also shows in the existing connected networks. Only five types of weather and climate information are being shared among rice farmers: 1) tropical cyclone; 2) rainfall forecast; 3) flood; 4) *El Niño*; and 5) *La Niña*, while seven types of weather and climate information have connected networks among corn farmers: 1) wet season; 2) dry season; 3) tropical cyclone; 4) drought; 5) rainfall forecast; 6) *El Niño*; and 7) thunderstorm.

The network graphs in Figure 2 and the network metrics in Table 4 support the finding that rice farmers prioritize the information on tropical cyclones significantly more than any other type of weather and climate information (Figure 3). Table 4 shows that this particular weather and climate information has the highest number of connected nodes (247) and, consequently, only has 14 isolated nodes. However, information sharing is minimal among rice farmers themselves (average degree = 0.96) and the information is centralized from the television with an outdegree measure of 215 compared to the total observed ties of 358 in the network. Network density is 0.5%, indicating a small number of observed ties compared to the total potential number of connections. In Figure 2, the core of the network consists of both focal and snowball nodes that directly rely on television, while the nodes in the periphery of the network gain access to information from other nodes that serve as bridges that relay the information to them. In a network where information is centralized, such as on tropical cyclones, communication among nodes is observed to be less (Ergun and Usluel 2016).

For corn farmers in Narra, a simple comparison of the network graphs shows that information on the wet season (Figure 4) and the dry season (Figure 5) are equally important and both are prioritized over other types of information with a connected network (Figure 6). The rest of the weather and climate information not shown in Figure 6 does not have any connections since these were neither used by the farmers nor accessed by them. The main sources of information on the wet and dry seasons are those with relatively higher measures of outdegree indicating where other nodes in the network get their information from. These are the television, a farmer leader (G13), the moon calendar, and the internet.

Table 4. Rice farmers' network metrics and sources of information.

Weather and Climate Information	Connected Nodes	Isolated Nodes	Ties	Density (%)	Main Source/s (Outdegree)
Tropical cyclone	247	14	358	0.5	Television (215)
Rainfall forecast	22	239	33	0.05	Television (18)
Flood	7	254	6	0.009	Television (2)
El Niño	4	257	6	0.009	Television (2)
La Niña	4	257	4	0.006	Television (2)

*total nodes in the network = 261.

Moreover, an extension worker assigned in the barangay was able to source and disseminate information about drought and rainfall in the network (Table 5).

Networks with high measures of density are highly interconnected, increasing the aggregate volume and speed of the flow of information (Gnyawali and Madhavan 2001) as well as innovativeness (Meagher and Rogers 2004). In contrast, networks with low-density measures populated by isolated nodes, such as the networks in this study, have an inefficient (lesser and slower) transmission of information (Lizardo and Jilbert 2020; Homish and Leonard 2008). While increasing the overall network density of weather and climate information among rice and corn farmers would be a logical recommendation to increase the transmission of information, it would be more appropriate to use the intergroup structure of information networks (on tropical cyclones and the wet and the dry seasons) than seek improvement in the larger network that has reduced strength of relationships between actors (Aidoo and Freeman 2016). High network densities also dampen the degree of centrality advantage that exists with rice and corn farmers. Simulation models by Gibbons (2007) show that the direct ties from the source (indegree and outdegree) have a greater influence in information

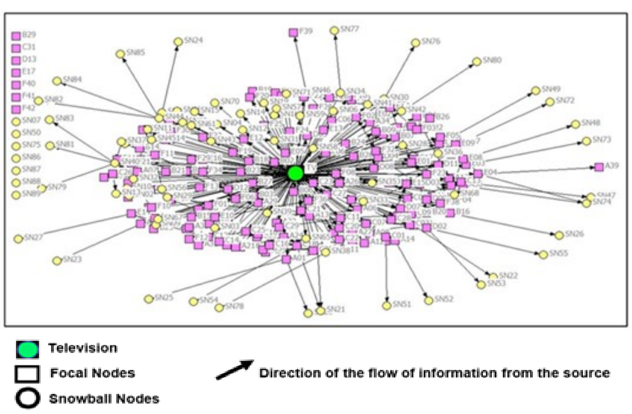

Fig. 2. Network of information on tropical cyclone among rice farmers in Biga, Calapan City.

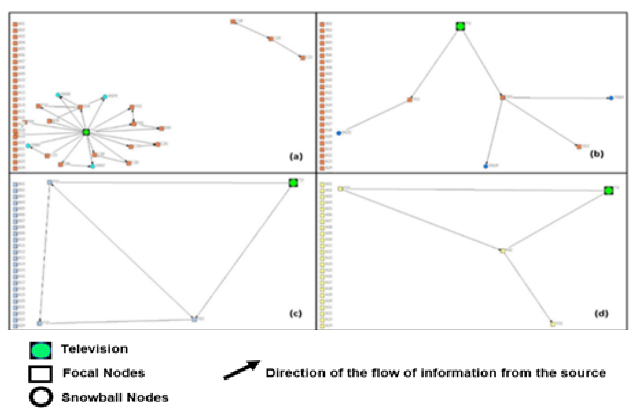

Fig. 3. Other types of weather and climate information shared among rice farmers in Biga, Calapan City: (a) Rainfall forecast; (b) Flood: (c) *El Niño*; (d) *La Niña.*

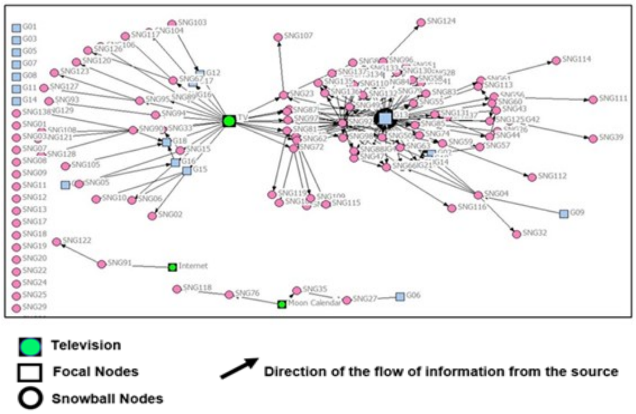

Fig. 4. Network of information on the wet season among corn farmers in Narra, Gloria.

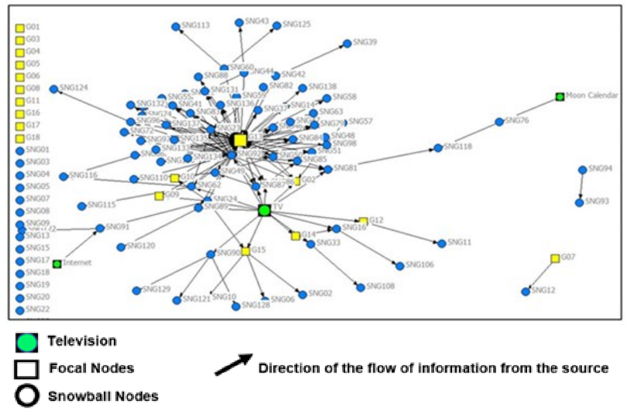

Fig. 5. Network of information on the dry season among corn farmers in Narra, Gloria.

diffusion than network density. Increasing the number of ties that directly source the information from the diffuser, for example, the television, can facilitate the spread of information better than relying on a loosely connected larger network. Gibbons (2007) also shows that it is likely to be most helpful for sparsely connected networks to reach out to nodes that are not already involved with one's contacts. Identifying these influential nodes that occupy a central position in both the level of particularly important weather and climate information networks and the whole network could serve as bridges to nodes that are isolated, increasing the transmission of information.

Table 5. Corn farmers' network metrics and sources of information.

Weather and Climate Information	Connected Nodes	Isolated Nodes	Ties	Density (%)	Main Source/s (outdegree)
Wet Season	111	49	226	0.9	Television (22), G13/farmer leader (49), Internet (1), moon calendar (2)
Dry Season	83	77	189	0.74	Television (15), G13/farmer leader (43), Internet (1), moon calendar (1)
Tropical Cyclone	21	139	20	0.08	Television (18)
Drought	10	150	16	0.06	SNG24/extension worker (5), Television (2)
Rainfall	11	149	14	0.06	SNG24 (4), Television (3)
El Niño	7	153	6	0.02	SNG44 (5), Television (1)
Thunderstorm	3	157	5	0.02	G13/Farmer leader (2)

**total nodes in the network = 160.*

Influential Farmers and Their Potential Roles

Mapping the flow of information on the weather and climate reveals that there are multiple sources and pathways of information, but with television as the common disseminator of information on tropical cyclones, the wet season, and the dry season. By excluding television, the maximum indegree (7) and outdegree measures (4) among rice farmers in the tropical cyclone network are very low in proportion to the network population (260). However, this also means that despite the norm among farmers to source information directly from television, rice farmer leader B03 has the highest indegree value received from at least seven different sources (neighbors, relatives, and close friends). This indicates that the farmer can have more iterative access to multiple warnings and advisories about the tropical cyclone than most of the farmers in the barangay. Characterizing these direct connections of farmer leader B03 can enhance the network's access to timely information before, during, and after a tropical cyclone.

This increase in access can potentially become more efficient, reaching peripheral or even isolated nodes in the network by taking advantage of the position of the node with the highest betweenness centrality measure. In the Biga tropical cyclone network, these nodes have at least 25 years of farming experience with membership to a barangay level farmers' organization, except for one (Table 6). Nodes with a high betweenness centrality value serve as 'bridges' by passing the information between farmers. Making these farmers direct contacts of

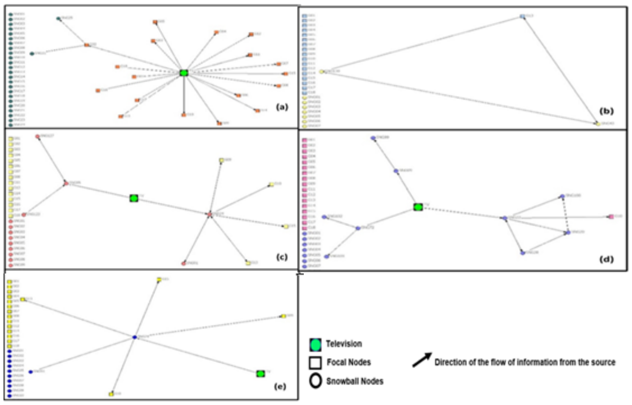

Fig. 6. Other types of weather and climate information shared among corn farmers in Narra, Gloria: (a) tropical cyclone; (b) drought; (c) rainfall forecast; (d) *el niño*; (e) thunderstorm.

a source of information can transmit the information across a wider range. Isolated and peripheral nodes can also benefit from connecting with these farmers to bridge the information from them.

Compared to the tropical cyclone network of rice farmers, the wet season and dry season networks of corn farmers have relatively higher maximum indegree measures than the average (1.05). While the television remains the main source of information on the wet season and dry season by the corn farmers, the maximum outdegree measure of a farmer is also relatively high (average = 20.3). In particular, farmer G13 has the highest indegree measure in both the wet season (48) and dry season (49) networks, while farmers G13 and SNG92 have relatively high outdegree measures across the network population in both the wet season (49 and 43, respectively) and the dry season networks (43 and 42). Calculating the indegree and outdegree measures reveals the farmers who function as the information pool (G13) and the transmitters (G13 and SNG92).

Looking at the betweenness centrality measures of corn farmers, the farmer who appears to be the most influential in the network (G13) has only been farming corn for five years, but is among those with the highest annual income (Tables 7 and 8). Farmer G13's influential position in the network can be attributed to her position as the leader of the local farmers' organization and her influence over those who rent land from her. Likewise, all of the nodes with high betweenness centrality are all members of that local organization.

At the level of the whole network, where all connections are visualized regardless of the type of weather and climate information, the significance of snowballing is apparent but differentiated in the information network of rice (Figure 7) and corn farmers (Figure 8). In both cases, snowball sampling has significantly captured the network population that would have been hidden if a sample frame based on the official list of farmers from the local agriculture office had been used. This generated an almost complete listing of those farming rice and corn in the study sites that can be used by the agricultural extension worker in the delivery of agroclimatic information as well as technologies.

The whole network density of corn farmers in Narra (0.7%) is higher than that of the Biga whole network (0.02%). The connections among corn farmers are denser as reflected by its network structure where there are two types of connected networks (Figure 8): in one the identified influential node G13 is the core; and in the other, some pairs are disconnected from the rest of the network. The core of the G13-centric network comprises the snowball nodes that have direct, reciprocal linkages with G13. These nodes are all members of the local farmers' organization where node G13 is the president. In the periphery of this network are G13's secondary contacts, with no direct link to the most central node. Nodes that can benefit from connecting to G13's primary contacts are isolated nodes and those further away in the margins, including the isolated pairs. Connecting to G13's network, a node can access the range of information as well as other resources that G13 pools from several sources. In this sense, node G13 serves as a gatekeeper of the local farmers' organization. Farmer G13 also acts as the main diffuser of information with the highest outdegree measure in the whole network (43). In the case of corn farmers in Narra, the local farmers' organization, represented by G13, functioned both as the pool or gatekeeper and the disseminator of information. Although there is also a local rice farmers' organization

Table 6. Rice farmers in the Biga tropical cyclone network with the highest measures of betweenness centrality.

Rank	Node	Bet. Score	Age	Ave. Annual Income (2018) Php	Org Member (1 yes/0 no)	Tenure Status (0 tenant/1 owner/ 2 ariendo)	Years Farming	Farm Land Area (ha)
1	C18	25	69	200,000	1	0	45	5
2	A36	21	46	100,000	1	1	30	2
3	F17	18	46	105,400	1	1	31	1.5
4	E04	16	62	70,000	1	0	40	1.25
5	F32	15	38	150,000	0	0	25	4

Table 7. Top 5 highest betweenness scores in Narra wet season network.

Rank	Node	Bet. Score	Age	Ave. Annual Income (2018) Php	Org Member (1 yes/0 no)	Tenure Status (0 tenant/ 1 owner/	Years Farming	Farm Land Area (ha)
1	G13	3415.5	59	340,000	1	1	5	2
2	SNG23	120.88	59	50,000	1	2	20	0.25
3	SNG72*	111.88	65	<40,000	1	1	52	1
4	SNG60*	108	53	<40,000	1	0	12	0.5
5	SNG92	86.88	58	40,000	1	1	39	0.75

*rice farmer

Table 8. Top 5 highest betweenness scores in Narra dry season network.

Rank	Node	Bet. Score	Age	Ave. Annual Income (2018) Php	Org Member (1 yes/0 no)	Tenure Status (0 tenant/ 1 owner/ 2 ariendo)	Years Farming	Farm Land Area (ha)
1	G13	2336.5	59	340,000	1	1	5	2
2	SNG92	203.5	58	40,000	1	1	39	0.75
3	SNG62**	73.83	61	<40,000	1	0	40	1.75
4	SNG89***	50	68	20,000	1	1	40	0.1
5	SNG81***	49	46	20,000	1	1	7	0.25

**rice farmer

*** vegetable farmer.

in Biga, the organization does not function in the same way. The Biga whole network is characterized by sparsely distributed one-way connections (Figure 7). The farmer who serves as the pool of information from several sources is node B03 (indegree = 6), who is the same influential node in Biga's tropical cyclone network. Like G13, node B03 is the president of the local farmers' organization in Biga, but with a different network of connections. A consequence is that in Biga, the main diffuser with the highest outdegree value (7) in the whole network is SN44. Also, this low outdegree value suggests that the information is not reaching the network population.

The nodes with the highest betweenness centrality scores in the whole network of rice and corn farmers are listed in Tables 8 and 9, respectively. In Biga, farmers A36, F04, C18, F17, and E04 have the highest scores, while farmers G13, G10, SNG49, G02, and SNG72 have the highest betweenness measures in Narra (Figures 7 and 8). Calculating the betweenness centrality score allows identifying gatekeepers and bridges in the network. They impose a strategic role by having the capability to serve as a 'bridge' and connect between other nodes that are otherwise disconnected in the network (Kamau et al. 2018). The position of these farmers is crucial in directing the flow of information throughout the network since they can either

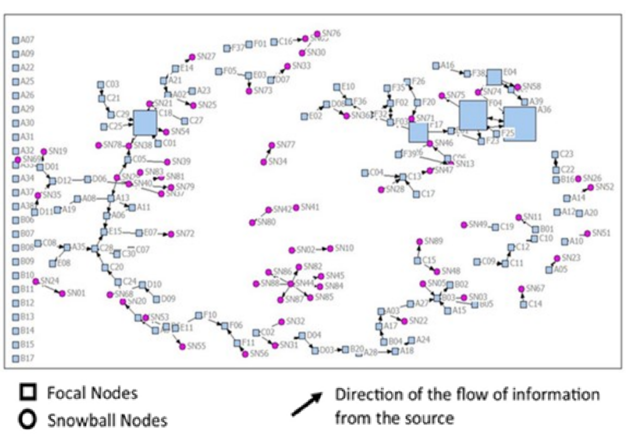

Fig. 7. Whole network of weather and climate information among rice farmers in Biga (node size by betweenness centrality).

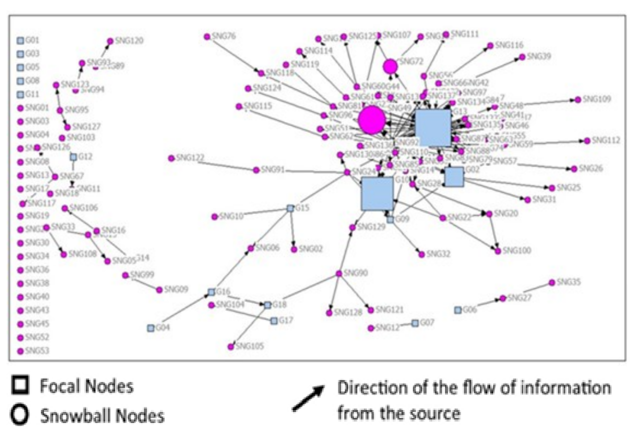

Fig. 8. Whole network of weather and climate information among corn farmers in Narra (node size by betweenness centrality).

Table 9. Top 5 highest betweenness score in Biga whole network.

Rank	Node	Bet. Score	Age	Ave. Annual Income (2018) Php	Org Member (1 yes/0 no)	Tenure Status (0 tenant/ 1 owner/	Years Farming	Farm Land Area (ha)
1	A36	30	46	100,000	1	1	30	2
2	F04	28	44	140,000	1	0	34	1
3	C18	20	69	200,000	1	0	45	5
4	F17	20	46	105,400	1	1	31	1.5
5	E04	18	62	70,000	1	0	40	1.25

Table 10. Top 5 highest betweenness score in Narra whole network.

Rank	Node	Bet. Score	Age	Ave. Annual Income (2018) Php	Org Member (1 yes/0 no)	Tenure Status (0 tenant/ 1 owner/ 2 ariendo)	Years Farming	Farm Land Area (ha)
1	G13	916.33	59	340,000	1	1	5	2
2	G10	124.16	51	40,000	1	2	2	0.50
3	SNG49*	57.50	38	15,000	1	0	5	1
4	G02	38	43	50,000	1	2	1	0.25
5	SNG72*	38	65	40,000	1	1	10	2

disseminate or not. The absence of participation of these bridge farmers could result in lesser information flow throughout the network. Poudel et al. (2015), further emphasized that "it could be dangerous and could be a point of failure for the social network if [bridges] leave farming, migrate to other places, or die". Likewise, the nodes who gained low betweenness scores may impose redundancy since there are other paths where a node might cross from one side of the network to another (Kamau et al. 2018).

Like the nodes with relatively high measures of indegree (pool) and outdegree (diffuser), the common characteristics of these farmers with high betweenness centrality scores is that they are members of the local farmers' organization (Tables 9 and 10). It is also observed that the influential node in the specific weather and climate information network in Narra, is also the identified influential node at the level of the whole network, farmer leader G13. Through the snowball method, influential nodes that are otherwise hidden were located and determined. Although these snowball nodes (SNG) were not registered on the municipal agriculturist's list of farmers, they possess very important positions in the network.

Due to the loosely dense, highly centralized, and multiple disconnected one-way pairs in the access network for weather and climate information, many farmers, especially rice farmers appear to use the information autonomously. However, there are nodes in the networks whose reach can potentially influence their peers and improve the delivery of weather and climate information (bridges), and those who gain information from multiple sources (information pool or gatekeeper). These influential farmers either occupy a local leadership position or are members of a farmers' organization and who, in most cases, have been farming for at least 25 years. These farmers can serve as a 'bridge' to other farmers who are isolated or peripheral in the network. The delivery of information can be improved if peripheral and isolated nodes can connect directly or even to the primary contacts of these influential nodes. However, implementing this recommendation can be more complicated without looking into the farmers' decision-making, specifically how they use the weather and climate information.

Use of Weather and Climate Information

The rapid ethnographic assessment highlights how farmers use weather and climate information based on their forecasting methods, who they consult with when they decide, and occasions when they would decide as a group. Although television is the most common source of W&C information, according to the survey, they have more ways of anticipating the weather. Farming knowledge is experience-based and does not solely rely on the forecasts, warnings, or advisories from PAGASA being broadcast on television or radio.

Rice farmers' forecasting is based on how the clouds, the sky, the wind, the sun, or the rain interact with Mt. Halcon, a prominent landscape feature in Oriental Mindoro. This kind of forecasting is combined with knowledge on bioindicators of the weather. For example, the presence of a particular bird can tell the farmer if the bad weather will persist or not. The flight of the layang-layang (swiftlet) indicates whether the summer season (flying low) or the rainy/typhoon season (flying high) is approaching.

Rice farmers decide on their own or with their spouse or with their traskuhan (farm overseer), especially when the farmer is old and can no longer manage the farm on their own. There is some level of coordinated action regarding the schedule of planting based on the following considerations: 1) fields are within the irrigated area of the NIA and hence they should follow the schedule of irrigation; 2) to prevent pests and diseases from attacking a small plot, they need to start cropping synchronously; and 3) parcels on the periphery should mature first, so the mechanized harvester can begin from the edges. The Biga Farmers' Association and the Irrigators' Federation function as an alliance network that can be used for information sharing. This network is activated only under certain circumstances, such as payments for irrigation canal maintenance, the start of cropping, and a program from the City. The president of the association (B03), the extension worker, and the water master of NIA can call for a gathering to activate this alliance network.

Information about these considerations is highly significant to rice farmers, more than knowing the scientific information about the weather and climate. There is anxiety among farmers about the weather and climate information being broadcast, especially when they perceive that nothing can be done if the weather will be unfavorable. For example, the assurance that they can still harvest even on rainy days and sell the wet rice (*basang palay*) at a fair price is more important for the farmer than knowing how to get an accurate forecast of the weather and climate during the harvest season.

Corn farmers in Gloria also hold another bank of farming knowledge. Individual farmers predict the rain on the day by reading the direction of the wind and the shape of the clouds rather than relying on the forecast. Knowing if it is likely to rain informs farmers in deciding when they will prepare and apply fertilizers. In particular, corn farmers renting the land of farmer leader G13, the president of the farmers' association in Narra, use the moon calendar to decide when they will start planting; the soil must be moist, but not sticky and muddy. Corn farmers avoid planting during a New Moon when they say it usually rains and instead plant during a Full Moon and when it is low tide.

Information on tropical cyclones, the wet season and the dry season are considered important for rice and corn farmers because they perceive that by using this information, financial losses and crop damage can be minimized, as cited by more than 70% of respondents from both Biga (183) in Calapan City and Narra (112) in Gloria. Rice farmers (43%) and corn farmers (21%) believe that having access to important weather and climate information can increase their yield. Harvesting and marketing their crops early before a disaster occurs, for example, a typhoon, is perceived as the least significant benefit to both rice farmers (82) and corn farmers (6). Although they were able to save the crops from the expected damage, the prices they received from selling the crops could be disappointing due to its low quality (*kala* or discoloration due to storing the damp grains).

Farmers also seek government advisories in the event of an *El Niño* or pests and diseases to determine if it is strategic to delay the cropping season and avoid imminent damages. While it seems economical to not farm during an *El Niño* if the farmer is not equipped with agro-technologies for alternative water supply or drought-resistant varieties, most farmers still opt to take the risk since they have no alternative livelihood and are not exempted from paying their lease.

It is an important finding and implies that even if there is an accurate set of weather and climate forecasts, warnings, or advisories available to the farmer, their current state of precarity pressures them to take the risk of loss and a chance for profit. Agricultural precarities should not be taken out of the picture in climate studies and farm decision modeling. This is important because the farmers' experience of precarity significantly influences their perception of the usefulness of weather and climate information and consequently how they use it.

CONCLUSION

To map the access and use of weather and climate information, we rely on the robustness of social network analysis in identifying which information matters as well as the potential of strategically positioned farmers to enhance the access to information in the network, while the rapid ethnographic assessment explains how different knowledge systems are used to inform farm decisions. SNA shows that not all types of weather and climate information are accessed and used by farmers. Rice farmers rely on the television for tropical cyclone advisories, while corn farmers share information on the rainy and the dry seasons much more extensively in the network than any other types of W&C information. Access to weather and climate information can be improved by using the nodes in the network with high betweenness centrality. These potentially influential nodes can be used to reach the isolated nodes, disconnected pairs, and the peripheral network directly or indirectly through their primary contacts. The database generated from the snowball sampling frame illustrates that there is a hidden population of farmers in the barangay. The agricultural extension worker can use this new listing and include all of the farmers in the programs and projects of the government. Lastly, results from the rapid ethnographic assessment show that the main purpose of accessing official W&C information is to avoid damages from disasters such as typhoons and *El Niño*. But daily weather forecasting and decisions on when to start the cropping cycle is multi-faceted and involves the farmers' local ecological knowledge, social circumstances, and market relations.

This study recommends that the co-development of agroclimatic products use scenario-based assessments with influential nodes in the network rather than relying on top-down dissemination of technical W&C information. Despite the emphasis on the accuracy and efficient delivery of forecasts and advisories, climate studies and farm decision modeling should also include narratives on agricultural precarities and explore how these are transforming agriculture in the age of climate change.

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