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Building Networks of Knowledge Exchange in Agricultural Meteorology: The Agro-Meteorological Service in French Indochina

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Introduction

Since its inception, the science of meteorology has been marked by transnational ambitions. Networks of observers spread across different nations and collecting meteorological observations can be dated back at least to the seventeenth century, when the Italian Accademia del Cimento (Academy of Experiment) organised a pan-European network to gather weather data.[1] In the second half of the nineteenth century, the transnational ambitions of meteorology were further strengthened with the creation of the International Meteorological Organization (IMO), one of the first scientific organisations devoted to international cooperation. The IMO was founded to establish global standards in meteorology and to promote the sharing of meteorological data and knowledge among the weather services of the participating countries.[2] The IMO members came from all over the world: from the European countries and their colonies, from Russia and later the Soviet Union, from the United States and Canada, from Brazil and Argentina, from Japan and, after WWII, also from China.

Even though European members always formed the overall majority and the meetings of the organisation never took place outside of Europe and North America, the IMO remains a privileged context for examining the transnational aspects of making and communicating meteorological knowledge that are the focus of this special issue. The IMO and its regular meetings—halted only during the two world wars—offered meteorologists the opportunity to discuss national practices with their peers, debate over the design of instruments for collecting and sharing meteorological data, and learn from each other. Through these debates and collaborations, which are recorded in the proceedings of the IMO meetings, networks of knowledge exchange were built and information on weather and climate circulated all over the

[1] James R. Fleming, "Early History of the Meteorological Observing Systems," in *Sciences of the Earth: An Encyclopedia of Events, People, and Phenomena*, ed. Gregory A. Good (New York and London: Garland Publishing Inc., 1998), 556-558.

[2] Hendrik G. Cannegieter, "The History of the International Meteorological Organisation 1872-1951," *Annalen Der Meteorologie*, Neue Folge, 1 (1963): 1–280; Paul N. Edwards, "Meteorology as Infrastructural Globalism," *Osiris* 21, no. 1 (2006): 229–50.

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world. In my paper, I will use the IMO technical commission on agriculture as a case study to discuss how these networks of knowledge exchange worked.

The IMO technical commission on agriculture was created in 1913 and held its last meeting in 1947.[3] Among its founding members were the director of the French Weather Bureau, meteorologist Charles Alfred Angot (1848–1924), who had been teaching physics and meteorology at the National Agronomy Institute in Paris since 1879; the geographer and meteorologist Peter Ivanovich Brounov (1853–1927), who was a key figure in the development of agricultural meteorology in Russia; the French rural economist Louis Dop (1866–1935), who was for many years the vice president of the International Institute of Agriculture (IIA) and the person who first approached the IMO with the proposal to set up a technical commission on agriculture; the German meteorologist Richard Börnstein (1852–1913), who had been collecting meteorological observations at Prussian agricultural academies for decades; and the Italian meteorologist Luigi Palazzo (1861–1933), the director of the Central Office for Meteorology and Geodynamics in Rome, an institution which also wanted to promote agro-meteorological studies.[4]

Angot, Brounov, Dop, Börnstein, and Palazzo recommended that the International Meteorological Committee, the IMO's steering body, create a permanent commission for agricultural meteorology. They argued that the novelty and the complexity of the problems posed by agricultural meteorology required an *ad hoc* commission and that this commission should be staffed not only by meteorologists and climatologists, but also by agronomists and botanists, as the problems of agricultural meteorology were multidisciplinary.[5]

The IMO Commission for Agricultural Meteorology was tasked with gathering information on correlations between weather, climate, and agricultural output, and with suggesting best practices for forecasting key events for farmers, such as imminent frosts. The commission's members examined meteorological instruments and recording procedures employed in agricultural meteorology and made suggestions for increasing the number of stations collecting both meteorological and agricultural data. They also addressed the relevance of microclimatological factors to plant growth and the importance of preparing weather forecasts and communicating them to farmers. As envisioned by its founding fathers, the

[3] The IMO decided to establish a technical commission on agriculture in 1913, but World War I soon halted international cooperation in meteorology and the IMO Commission for Agricultural Meteorology held its first official meeting in Paris in 1919 (Cannegieter, "The History of the International Meteorological Organisation", 199). The commission worked regularly during the interwar years, but with the outbreak of World War II the IMO's activities again ceased. The commission held its last two meetings after World War II, in 1946 and 1947. For the history of the IMO Commission for Agricultural Meteorology, see Giuditta Parolini, "The International Meteorological Organization and Its Commission for Agricultural Meteorology After WWI," *Acta Historica Leopoldina*, forthcoming in 2020, and Giuditta Parolini, Sílvio R. Dahmen, and Sandra Prado, "Using Network Analysis to Investigate the History of Agricultural Meteorology," 13th Workshop on Historical Network Research, Mainz: Akademie der Wissenschaften und der Literatur, 2019, https://nats.hypotheses.org/files/2019/10/AbstractsParticipants_optimized-1.pdf.Parolini et al.

[4] More biographical information on the scientists who promoted the IMO technical commission on agriculture can be found in Anonymous, "Professor C. A. Angot [Obituary]," *Quarterly Journal of the Royal Meteorological Society* 50, no. 211 (1924): 270–71; Anonymous, "Luigi Palazzo, 1861–1933 [Obituary]," *Terrestrial Magnetism and Atmospheric Electricity* 39, no. 1 (1934): 71–72; Carl G. von Klinckowstroem, "Börnstein, Richard," in *Neue Deutsche Biographie 2 (online)*, 1955, https://www.deutsche-biographie.de/sfz5069.html. The IIA was founded in Rome in 1905 (Asher Hobson, *The International Institute of Agriculture: An Historical and Critical Analysis of Its Organization, Activities and Policies of Administration* (Berkeley: University of California Press, 1931)). Its mission was broad and ranged from the collection of official statistics related to worldwide agricultural production to the application of scientific knowledge to farming. During the first half of the twentieth century it was one of the most influential agricultural organisations. Today's FAO, the Food and Agricultural Organization of the United Nations, took over the IIA's legacy.

[5] International Meteorological Organization, *Bericht über die Versammlung des Internationalen Meteorologischen Komitees*, Veröffentlichungen des Königlich Preussischen Meteorologischen Instituts, no. 260 (Berlin: Behrend & Co., 1913).

commission was not only staffed by meteorologists and climatologists, but also by agronomists, botanists, geographers, and statisticians who contributed their scientific expertise to solve problems in agricultural meteorology.

Over three decades, 132 people in total joined the IMO technical commission on agriculture. Of them, about one-third were based outside of Europe and European Russia. These extra-European members were located in America (from Canada to Argentina), Africa, Australia, and Asia (Fig. 1). They worked in independent states, but also in protectorates and colonies of European nations. Their presence ensured that the IMO's work could circulate all over the world, from Santiago de Chile to Tokyo to Wellington. Their role, however, was not merely to convey the information gathered in international scientific circles to their home countries. They also contributed to the knowledge-making process, because they had first-hand expertise in growing tea, coffee, cocoa, and other crops precious for European economies, but not suited to the temperate climate, and therefore not studied by European agronomists, meteorologists, and climatologists.

I will argue that the IMO Commission for Agricultural Meteorology's networks of knowledge exchange were not one-way routes departing from Europe and leading to its present or former colonies or protectorates, but that they facilitated knowledge transfer towards Europe as well as from Europe. This is particularly evident in the case of the agro-meteorological service set up in French Indochina by the agronomist and climatologist Paul Carton (1891–1969).[6]

Born at Asnières, in Normandy, Carton received his training in agronomy, with a specialisation in tropical agriculture, at the French National Institute of Colonial Agriculture.[7] Before moving to Indochina, he worked as a technical writer for the IIA in Rome, and at this stage he became interested in the connections between weather, climate, and agriculture. These topics were widely discussed at the IIA, as demonstrated by the participation of its vice-president, Louis Dop, in the IMO technical commission on agriculture. During his time in Indochina, Carton became a member of the IMO commission and remained as such until the last meeting in 1947. He was also among the advisers who attended the first meeting of the Commission for Agricultural Meteorology (CAgM), which was reconstituted within the World Meteorological Organization in 1953.[8]

Carton was a very active member of the IMO Commission for Agricultural Meteorology. He was eager to learn from the scientific and technological developments taking place in Europe, but at the same time he was also ready to present the work his agro-meteorological service did in Indochina, and to point out the importance of studying tropical crops, such as rice, alongside temperate crops. Furthermore, Carton's interests were not confined to agricultural meteorology: they also included the cognate discipline of agricultural ecology, and Carton became a member of the Commission for Agricultural Meteorology and Ecology set up by the IIA in Rome.[9]

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[6] French Indochina encompassed an area roughly comprising today's Vietnam and nearby territories in Laos and Cambodia.

[7] Max Vachon, 'Carton, Paul', in *Dictionnaire Biographique d'Outre-Mer*, 1975, https://wbis.degruyter.com/biographic-document/R14688.

[8] WMO, *Commission for Agricultural Meteorology (CAgM): Abridged Final Report of the First Session*, WMO Publication no. 27 (Geneva: WMO, 1954).

[9] Girolamo Azzi and Pietro R. Pirotta, "International Institute of Agricultural Ecology," *International Review of the Science and Practice of Agriculture*, New Series, 3, no. 3 (1925): 766–81.

In my paper, I will use Carton's agro-meteorological service in French Indochina as an example of the IMO's involvement in the circulation of meteorological knowledge between East and West. To provide a context for understanding the case of French Indochina, I will begin with a discussion of the IMO Commission for Agricultural Meteorology and its commitment to facilitate knowledge exchange among its members. I will then provide an overview of the extra-European members and their involvement in the commission's work before discussing the case of French Indochina. For the latter, I will not only describe how the service was established, but also how Carton used his membership in international organisations to acquire and share information on agricultural meteorology, and the reasons that brought him to pursue both agricultural meteorology and ecology. In conclusion, I will discuss how the networks of knowledge exchange established by the IMO Commission for Agricultural Meteorology were based on a two-way exchange of information and how this was necessary to acquire knowledge on key commodities produced in tropical areas and heavily used in Europe.

Members of the IMO Commission for Agricultural Meteorology based in America, Africa, Asia, Australia

Map made with QGIS. Base map by ©OpenStreetMap

Fig. 1. Map displaying the location of the IMO Commission for Agricultural Meteorology's members outside of Europe.

Networks of Knowledge Exchange in Twentieth-Century Agricultural Meteorology

In the twentieth century, agriculture was one of the first sectors to develop systematic methods for collecting and exploiting weather information.[10] At the end of the nineteenth century, Russia pioneered the creation of agro-meteorological services.[11] The Russian Ministry of Agriculture's Bureau of Meteorology was established in 1896 and managed a network of agro-meteorological stations, which counted over 70 stations in 1912.[12] Peter Ivanovich Brounov, one of the IMO technical commission on agriculture's founding fathers, was a key figure in the development of agricultural meteorology in Russia. Brounov's Bureau in St. Petersburg supervised the agricultural and meteorological observations collected by the Russian stations, acquired the resulting data via questionnaires, and summarised and published these data. The Russian agro-meteorological service had two main aims. The first was to study the correlations between crop growth and meteorological factors, and to produce forecasts useful for farmers. The second was to investigate the distribution of crops according to Russian climatic regions and to suggest the best plant varieties for each area.

If Russia paved the way in agricultural meteorology, other countries quickly followed suit. By the early 1920s, the US Weather Bureau already had an established network of (mainly voluntary) observers based in the agricultural districts. The data collected were used to provide specialised services to farmers. The Weather Bureau produced daily or weekly bulletins of rainfall and temperature, and, when required, frost warnings, crop-weather bulletins, and so on. In the US, meteorological information was disseminated by telegraph, by telephone, and in print, because it was essential that it reach farmers quickly.[13]

Several other nations, such as Great Britain, France, Italy, Poland, and Japan, established agro-meteorological services or were interested in doing so during the first three decades of the twentieth century.[14] These agro-meteorological services were staffed by meteorologists and agronomists and always relied on a network of local stations to collect both meteorological and agricultural data. They aided the national farming community by compiling weather bulletins and preparing weather forecasts, but they also promoted scientific investigations on the correlation between weather and agricultural output.

The work of agro-meteorological services usually also included research on the influence that climate, in general, and microclimate, in particular, had on plant growth.[15]

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[10] Vladimir Janković, "Working with Weather: Atmospheric Resources, Climate Variability and the Rise of Industrial Meteorology, 1950-2010," *History of Meteorology* 7 (2015): 99.

[11] John W. Smith, *Agricultural Meteorology: The Effect of Weather on Crops* (New York: The MacMillan Company, 1920), 24–25.

[12] Peter I. Brounov, "Some Considerations of the Organization of the Agricultural Meteorological Service," *Bulletin of Foreign Agricultural Intelligence* 6 (1916): 309–14.

[13] Gustavus A. Weber, *The Weather Bureau: Its History, Activities and Organization*, Service Monograph of the United States Government no. 9 (New York and London: D. Appleton and Company, 1922).

[14] Girolamo Azzi, "Per la organizzazione di un servizio di meteorologia agraria," *Rivista Meteorico-Agraria* 33, no. 36 (1912); Organisation Météorologique Internationale, *Commission de Météorologie Agricole: Procés verbaux de la 2ième réunion, Zurich, 1926* (Stockholm: Statens Meteorologisk-Hydrografiska Anstalt no. 256, 1927); Ministry of Agriculture and Fisheries, "The Weather and Agriculture in the British Empire," *Journal of the Ministry of Agriculture* 36 (1929): 657–62; Émile Delcambre, "Sur l'activité scientifique de l'Office National Météorologique, notamment dans ses rapports avec l'agriculture," *Comptes rendus hebdomadaires des séances de l'Académie d'Agriculture de France* 19 (1933): 413–23; Jean Lugeon, *Les travaux de météorologie agricole de l'Institut National Météorologique de Pologne* (Warsaw: Wydawnictwo Specjalne Z Okazji Zjazdu Miedzynarodowej Organizacji Meteorologicznej, 1935).

[15] Rudolf Geiger, *Das Klima der bodennahen Luftschicht: ein Lehrbuch der Mikroklimatologie.* (Braunschweig: Verlag Friedrich Vieweg and Sohn, 1927); Girolamo Azzi, *Le climat du blé dans le monde: Les bases écologiques de la culture mondiale du blé* (Rome: Institut International d'Agriculture, 1930).

Climatological considerations were essential to select the varieties best suited for cultivation in a certain area. Better knowledge of microclimatology was also crucial, because the atmospheric layers closer to the ground and the soil conditions were key factors in the growth of crops and fruit trees.

The interest in climatological and microclimatological studies was shared by the cognate discipline of agricultural ecology, which also developed in the early twentieth century alongside agricultural meteorology. Girolamo Azzi, a founding father of agricultural ecology,[16] defined it as:

> the study of the physical characteristics of environment, climate and soil, in relation to the development of agricultural plants, and to the yield of such plants from the quantitative (amount of the product), qualitative (quality of the product), and generative (characters of the seed) points of view.[17]

Azzi's monograph, *Le climat du blé dans le monde* (1930) (Wheat Climates of the Earth), which was aptly subtitled *Les bases écologiques de la culture mondiale du blé* (the ecological basis of worldwide wheat cultivation), was a first example of a global study that examined both climatological and agricultural factors in the cultivation of wheat, the main crop grown in temperate regions.[18,19] The project started in 1919, when memories of the famine and starvation caused by World War I in several European countries were still a painful memory. The IIA promoted the research and assigned it to Azzi, due to his long-term involvement in agricultural ecology in Italy. The data collection work lasted for years and Azzi's research was eventually submitted as a report to the first International Conference on Wheat, held in Rome in 1927. During this meeting, which was sponsored by the Italian Fascist government, it was decided to establish an international network of agro-ecological stations to monitor wheat cultivation worldwide. However, the project never really took off, because the Italian Fascist government's politics interfered with the IIA's scientific activity and hindered international collaboration.

The two domains of agricultural meteorology and ecology were interconnected and practitioners of agricultural ecology, such as Girolamo Azzi, were also members of the IMO Commission for Agricultural Meteorology. Azzi's work on agricultural ecology deserves a special mention in this paper, because it had a long-lasting influence on Paul Carton and on his agro-meteorological service in French Indochina. Carton met Azzi early on in his career, while he was working at the IIA in Rome, and their friendship continued throughout the decades. He regularly cited Azzi's publications in his scientific papers and, in the 1950s, he wrote the preface for the French edition of Azzi's textbook on agricultural ecology.[20]

The IMO Commission for Agricultural Meteorology's mission was to facilitate knowledge exchange among the participating nations. The commission was a forum for discussing the meteorological data useful in agricultural meteorology and the most suitable instruments for measuring and collecting them. It enabled the exchange of best practices in data management and weather forecasting and the sharing of references to the publications

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[16] Corey Ross, *Ecology and Power in the Age of Empire: Europe and the Transformation of the Tropical World* (Oxford: Oxford University Press, 2017), 336.

[17] Girolamo Azzi, *Agricultural Ecology* (London: Constable and Company, 1956), xiii. The original Italian version was published in the 1920s.

[18] Azzi, *Le climat du blé dans le monde*.

[19] If not otherwise specified, all the translations from French are mine.

[20] Girolamo Azzi, *Écologie agricole* (Paris: Ballière, 1954).

produced by each nation.[21] As part of its mission, the commission also actively promoted international cooperation in setting up observational schemes in agricultural meteorology, for instance in phenology, lobbied for the development of worldwide experimental schemes for testing the correlation between weather conditions and crop growth, and liaised with other international organisations interested in agricultural meteorology, such as the IIA.

Almost 40 nations and their colonial empires were represented in the IMO Commission for Agricultural Meteorology during its existence. This wide geographic distribution was a resource for the commission's work, as agriculture is a geographically-located enterprise and work in agricultural meteorology can only be conducted where the crops grow.[22] Extensive geographic coverage was also essential to ensure the success of the commission's global observational and experimental schemes. The extra-European members contributed by bringing their experiences with tropical crops such as tea, coffee, and cocoa, which were so relevant for Western economies in the first half of the twentieth century. Agronomists and meteorologists based in Europe had no direct knowledge of these crops, whose successful cultivation required skills and techniques very different from those employed for temperate crops. In the following section, I will therefore take a closer look at the members of the IMO commission based outside of Europe and at their contributions. From this brief survey, it will become apparent that Carton was one of the commission's most enterprising members and that he used the commission as a forum for acquiring knowledge of other countries' best practices, but also to disseminate information on the work of his service in Indochina.

Extra-European Members of the IMO Commission for Agricultural Meteorology

When the IMO Commission for Agricultural Meteorology was established in 1913, Canada was the only extra-European country represented, but when the commission was officially re-appointed after World War I, there were also members based in Australia and French Syria (now Lebanon). During the interwar years, members of the commission could be found in Brazil, Argentina, Chile, South Africa, (British) East Africa, Morocco, India, Batavia, Sri Lanka, French Indochina, New Zealand, and Japan. The geographic distribution widened further after World War II, when members from China, Palestine, Egypt, Rhodesia, Uruguay, and Peru also joined the commission. A few of these members joined the commission for only a short time, while others, like Carton, maintained their association for decades and actively contributed to the commission's work (Fig. 1 and Table 1).

The commission held regular meetings during the interwar years and after World War II. However, only a very limited number of members could attend these meetings, and the commission's work was mainly done via the correspondence network built around its president.[23] The president was in charge of producing regular reports, circulating them among the members, organising the publication of the commission proceedings, and collecting suggestions about topics to be discussed at forthcoming meetings. While the original correspondence is not available, the printed proceedings still provide a selection of these letters

[21] The proceedings of the IMO Commission for Agricultural Meteorology contain several short bibliographies of the publications produced by each nation on weather and crops. The creation of a journal of agricultural meteorology was also discussed, but not approved due to lack of resources. The IMO was, in fact, an organisation without an official status. It had only a small budget that just sufficed to support its secretariat, the publication of the conference proceedings, and a few other occasional publications considered of general interest for meteorologists.

[22] Giuditta Parolini, "Charting the History of Agricultural Experiments," *History and Philosophy of the Life Sciences* 37, no. 3 (2015): 231–41.

[23] Even the members of the commission based in Europe were often prevented from attending the meetings in person and participated in the commission's work by letter and telegram.

and allow us to reconstruct the contributions individual members made to the commission's work.

Despite delays due to the postal system, participation by correspondence facilitated the involvement of the extra-European members in the commission's activities. For instance, several meteorological services based outside of Europe, such as the Egyptian Meteorological Service and the Tokyo Central Meteorological Observatory, answered the questionnaire circulated in the early 1920s, which aimed to understand what kind of national agro-meteorological services were in operation and their agendas.[24] Things did not always proceed smoothly. For instance, Carton was able to send his comments on the agenda set for the 1929 meeting only later than requested, due to "[l'] éloignement de l'Indochine" (the remoteness of Indochina) and the consequent delays in receiving the communications sent by the commission's president.[25] Eventually, however, Carton's large correspondence on ten different topics, found a space in the printed proceedings.

Always by correspondence, the commission collected lists of publications on agricultural meteorology produced in the participating nations and members often sent in updates on their national services. This practice continued throughout the years. For instance, the Argentinian meteorological service, represented at the time by the agronomist Juan Jacinto Burgos, supplied several items submitted for the last meeting in Toronto.[26] These publications concerned multiple topics, ranging from the description of the most recent developments of Argentina's agro-meteorological service to scientific studies concerning frost prediction, soil moisture, and phenology.

Among the members based outside of Europe, Paul Carton stands out for his frequent contributions to the commission's work in the interwar years. From 1923, when he joined the IMO commission, he began to submit proposals on agricultural meteorology, with a specific focus on the tropical regions.[27] In his proposals he stressed both methodological issues (for instance, the co-existence of meteorological and ecological aspects in the investigations on weather, climate, and agriculture conducted by agro-meteorological services) and technical problems (such as the standardisation of instruments used by agro-meteorological stations).

Carton was aware of the scarce representation that tropical agriculture received in international organisations and tried to address this gap by providing detailed information on his work in Indochina. In response to the IMO commission's questionnaire of the early 1920s, Carton produced a long report on the agro-meteorological service that he was developing.[28,29] As part of the extensive correspondence between Carton and the president of the IMO

[24] Organisation Météorologique Internationale, *Commission de Météorologie Agricole: Procès verbaux de la 2ième réunion, Zurich 1926*, 34-85.

[25] Organisation Météorologique Internationale, *Commission de Météorologie Agricole: Procès verbaux de la 3ième Réunion, Copenhague, 1929* (Stockholm: Statens Meteorologisk-Hydrografiska Anstalt 276, 1929), 51.

[26] Organisation Météorologique Internationale, *Commission for Agricultural Meteorology Abridged Final Report, Toronto, August 1947* (Lausanne: Imprimerie La Concorde, 1949), 8–11.

[27] International Meteorological Organization, *Report of the International Meteorological Conference of Directors and of the Meeting of the International Meteorological Committee, Utrecht, 1923* (Utrecht: Koninklijk Nederlandsch Meteorologisch Instituut, 1924), 155–56.

[28] Organisation Météorologique Internationale, *Commission de Météorologie Agricole: Procès verbaux de la 2ième réunion, Zurich, 1926.*

[29] The report was written in collaboration with his colleague Étienne Bruzon, the director of the Indochina Central Observatory.

commission in 1929, this report was amended to provide information on the progress made during the intervening years and Carton regularly sent in updates afterwards.[30]

However, Carton's contributions to the commission's work went well beyond detailed reports on agro-meteorology in Indochina. They concerned wider topics, such as the relationship between agricultural meteorology and agricultural ecology, and they also dealt with practical details, such as the suggestion to publish the commission's proceedings in both English and French. Carton never had an opportunity to attend the interwar meetings of the commission, but he was always ready to give his opinion on the topics discussed, such as the best time unit to be employed in agricultural meteorology or the most suitable equipment to monitor microclimatological variables.[31]

Another recurrent topic in Carton's correspondence was the relationship between the IMO Commission for Agricultural Meteorology and the IIA Commission on Agricultural Meteorology and Ecology. As a member of both commissions, Carton was eager to promote their cooperation and to have an opportunity to participate in their work as a correspondent. To strengthen cooperation, he suggested that the IMO commission invite the members of the IIA commission to its meetings.[32] In addition, he constantly brought relevant topics examined by the IIA to the attention of the IMO commission, such as the methodologies to be employed in agricultural meteorology and the study of local climate and its influence on plant growth.[33]

Carton's active role in the international circles of agricultural meteorology was not only justified by scientific curiosity. In his communications with the president of the IMO commission, he repeatedly stressed the economic value of agricultural meteorology and ecology and the necessity of including tropical crops in scientific investigations:

> The members of the [IMO and IIA] commissions have been mainly interested in temperate crops. However, in the global economy, tropical crops are of equal importance. Consequently, it seems to me essential that an agreement be reached between the two commissions for a corresponding ecological study of tropical crops, in particular: rice (whose cultivation extends to temperate countries), coffee, tea, cotton and *hevea* [the rubber tree]. Unfortunately, very few representatives of tropical agriculture attend the meetings of the two commissions. Therefore, in order to establish the work programme to be undertaken and to carry it out successfully, it seems desirable that these experts should be consulted and be able to make contacts with each other.[34]

Carton suggested that the IIA act as a mediator in the effort to put tropical countries and their precious crops on the map, and constantly complained when the time allocated for commenting

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[30] Organisation Météorologique Internationale, *Commission de Météorologie Agricole: Procès verbaux de la 3ième Réunion, Copenhague, 1929* (Stockholm: Statens Meteorologisk-Hydrografiska Anstalt no. 276, 1929), 62–65.

[31] Organisation Météorologique Internationale, *Procès verbaux de la 3ième réunion, Copenhague, 1929*, 55.

[32] Organisation Météorologique Internationale, *Commission de Meteorologie Agricole: Procès verbaux des seances de Munich, 19–21 Septembre 1932* (Utrecht: Organisation Météorologique Internationale no. 14, 1933), 9.

[33] Organisation Météorologique Internationale, *Commission de Météorologie Agricole: Procés verbaux de la 3ième réunion, Copenhague, 1929,* 51–54.

[34] "Ce sont surtout les plantes des pays tempérés qu'ont eu en vue les membres des Commissions. Or, dans l'économie mondiale, les plantes des pays tropicaux sont d'une égale importance. En consequence, il m'apparaît indispensable qu'une entente ait lieu entre les deux Commissions en vue d'une étude écologique correspondante des plantes tropicales de grande culture, en particulier: le riz (dont la culture s'étend d'ailleurs aux pays tempérés), le caféier, le théier, le cotonnier et l'hévéa. Malheureusement, lors des réunions des deux Commissions, très rares sont les représentants de l'Agriculture tropicale. Aussi, pour établir le programme de l'étude à entreprendre et pour mener à bien son exécution, il semble qu'il serait désirable que ceux-ci fussent consultés et pussent entrer en relation entre eux" (Organisation Météorologique Internationale, *Procès verbaux de la 3ième réunion, Copenhague, 1929*, pp. 61–62).

on reports and initiatives was inadequate to allow members based outside of Europe to provide their opinion by correspondence.[35]

The coexistence of scientific knowledge on agricultural meteorology and ecology was always coupled with attention to the economic value of this knowledge in the agro-meteorological service that Carton set up in French Indochina. In this approach, Carton was certainly faithful to Azzi's understanding of agricultural ecology (and meteorology) as practical sciences useful in farm management.[36]

Name	**City**	**Nation geography (history)**
Balkan, Aziz	Ankara	Turkey
Bamford, Alec Joscelyne	Colombo	Sri Lanka (British colony)
Bates, Daniel Cross	Wellington	New Zealand (British dominion)
Bergeiro, José Maria	Montevideo	Uruguay
Berloty, (Révérend Père) Bonaventure	Ksara	Lebanon (French protectorate)
Bernard, Etienne A.	Yangambi	Democratic Republic of Congo (Belgian colony)
de Boer, Herman Johannes	Batavia	Indonesia (Dutch colony)
Boughner, Clarence Clarkson	Toronto	Canada (British dominion)
Burgos, Juan Jacinto	Buenos Aires	Argentina
Carton, Paul	Hanoi	Vietnam (French colony)
Connor, Abraham James	Toronto	Canada (British dominion)
Fahmy, Hassan	Cairo	Egypt
Feige, Rudolf	Jerusalem	Palestine (British mandate)
Ferraz, Joaquim de Sampaio	Rio de Janeiro	Brazil
Foley, James Charles	Melbourne	Australia (British dominion)
Girola, Carlos de Alberti	Buenos Aires	Argentina
Hirata, Tokutarō	Tokyo	Japan
Hirschhorn, Julio	Buenos Aires	Argentina
Jacobs, Woodrow Cooper	Washington	USA
Kincer, Joseph Burton	Washington	USA
Normand, Charles William Blyth	Pune	India (British colony)
Nuño, Waldo	Santiago de Chile	Chile
Okada, Takematsu	Tokyo	Japan
Patterson, John	Toronto	Canada (British dominion)

[35] Organisation Météorologique Internationale, *Commission de Météorologie Agricole: Procès verbaux de la 3ième réunion. Copenhague, 1929*, 53.

[36] Azzi, *Agricultural Ecology*, xii.

Peake, J. S.	Harare	Zimbabwe (British colony)
Pires Xavier, Raul	Rio de Janeiro	Brazil
Putnam, Donald Fulton	Toronto	Canada (British dominion)
Ripley, Philip Oscar	Ottawa	Canada (British dominion)
Roy, A. K.	Kolkata	India (British colony)
Sarle, Charles Faye	Washington	USA (British colony)
Schindler, Pierre	Casablanca	Morocco (French colony)
Seelye, Cassilis James	Wellington	New Zealand (British dominion)
Shutt, Frank Thomas	Ottawa	Canada (British dominion)
Smit, H. P.	Pretoria	South Africa (British dominion)
Smith, John Warren	Washington	USA
Stewart, Charles M.	Pretoria	South Africa (British dominion)
Sutton, L. J.	Cairo	Egypt
T'U, Chang Wang	Nanking	China
Taylor, Thomas Griffith	Melbourne/ Chicago/ Toronto	Australia (British dominion)/moved to USA/moved to Canada (British dominion)
Tiscornia, José	Montevideo	Uruguay
Walter, Albert	Nairobi	Kenya (British colony)
Zender Honig, Jacobo	Lima	Peru

Tab. 1. Members of the IMO Commission for Agricultural Meteorology not based in Europe or European Russia. Data extracted from Giuditta Parolini, "Membership of the IMO Commission for Agricultural Meteorology (1913-1947)", Mendeley Data, 2020, v1. http://dx.doi.org/10.17632/pds6tz443t.1.

The Agro-Meteorological Service in French Indochina

French colonial expansion in Indochina started in the 1860s in the area corresponding to today's South Vietnam. By the 1880s, the territories under French rule extended to Annam and Tonkin, and to nearby territories in Cambodia and Laos. These areas were formally brought together in the late 1880s in the Union Indochinoise Française (French Indochinese Union).[37] Indochina was one of the "new" colonies acquired by France after the Napoleonic era, and became part of a colonial empire whose geographic extension was second only to that of the British empire at the beginning of the twentieth century. In the 1930s, at the time of its maximum expansion, the French colonial empire counted 65 million inhabitants distributed in four continents: America, Africa, Asia, and Oceania.[38]

The systematic exploitation of natural resources in Indochina started at the turn of the twentieth century, when the French colonial government, its scientific institutions (such as the Pasteur Institute), and private businesses joined forces to establish profitable plantations. In

[37] Nicola Cooper, *France in Indochina: Colonial Encounters* (Oxford: Berg Publishers, 2001).

[38] Michael A. Osborne, "Science and the French Empire," *Isis* 96, no. 1 (2005): 80–87.

this *mise en valeur* (economic development) of the French colonies, science and scientific institutions played a primary role, especially after World War I.[39] As part of this effort, agricultural services and botanical research were among the first sectors to be reorganised after the conflict.

In Indochina the French colonisers were mainly interested in primary resources such as rice, rubber, and coffee, and, as such, agricultural development was key to ensuring the colony's increased profitability. In 1924 the colonial government established the *Inspection générale de l'Agriculture, de l'Elevage et des Forêts* (General Inspectorate for Agriculture, Breeding, and Forestry) and tasked it with the overall supervision and coordination of the agricultural services of the various provinces of the Indochinese Union.[40] Capital was also important for the economic development of agriculture in Indochina, and it was provided by, among others, the *Banque de l'Indochine* (Bank of Indochina), an institution created in the late nineteenth century to support French colonial expansion in Asia. In addition, the political authorities in Paris constantly implemented interventionist strategies to support the colonial economy in Indochina, especially during the global recession of the early 1930s.[41] By the late 1930s, rice and natural rubber extracted from *hevea* were the agricultural commodities that offered the highest returns and the French colonial administration focused on Indochina as one of the most promising colonial economies.[42]

Carton left France for Indochina in November 1920 and joined the French colonial service as director of the agronomy section of the *Institute Scientifique de l'Indochine* (Indochina Scientific Institute).[43] He maintained this position until 1922, when he became director of the *Bureau des Renseignements Agricoles* (Agricultural Information Bureau), which was part of the French colonial government's economic services in Indochina. In 1927, he was appointed chief of the *Bureau de Climatologie et de Météorologie Agricole* (Bureau of Climatology and Agricultural Meteorology) and he maintained this position until 1936, when he moved on to other advisory and teaching roles within Indochina's agricultural services.

Carton worked for over 20 years in Indochina and built his scientific career on the work in agricultural meteorology and ecology he did there.[44] He regularly published scientific contributions on weather, climate, and their impact on plant growth in the *Bulletin économique de l'Indochine* (Economic Bulletin of Indochina), in French journals of colonial agronomy (such as *Agronomie colonial* (Colonial Agronomy) and *Agronomie tropicale* (Tropical Agronomy)), and as part of the publications sponsored by the colonial administration.[45] Carton also wrote a textbook on agricultural ecology in connection with his teaching work at the *Ecole*

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[39] Christophe Bonneuil, *Des savants pour l'Empire: La structuration des recherches scientifiques colonials au temps de 'la mise en valeur des colonies françaises,' 1917–1945.* (Paris: Éditions de l'ORSTOM, 1991).

[40] Paul Carton, *La météorologie agricole en Indochine* (Hanoi: Imprimerie d'Extrême-Orient, 1930).

[41] Jonathan A. Bone, "Rice, Rubber, and Development Policies: The Mise En Valeur of French Indochina on the Eve of the Second World War," *Proceedings of the Meeting of the French Colonial Historical Society* 16 (1992): 154–80.

[42] Michitake Aso, 'The Scientist, the Governor, and the Planter: The Political Economy of Agricultural Knowledge in Indochina During the Creation of a 'Science of Rubber,' 1900–1940," *East Asian Science, Technology and Society* 3, no. 2–3 (2009): 232.

[43] All the biographic information on Carton is extracted from Vachon, "Carton, Paul".

[44] During the 1930s, Carton received awards from the French Agricultural Academy and the French Academy of Sciences for his work in Indochina.

[45] Émile Bruzon and Paul Carton, *Le climat de l'Indochine et les typhons de la mer de Chine* (Hanoi: Imprimerie d'Extrême-Orient, 1930); Paul Carton, *Contribution à l'étude du régime pluviométrique de l'Indochine* (Hanoi: Gouvernement général de l'Indochine, 1935).

supérieure d'agriculture et de silviculture de l'Indochine (Indochina College for Agriculture and Forestry).[46]

As chief of the Bureau of Climatology and Agricultural Meteorology, Carton was able to reorganise and expand the existing network of stations collecting meteorological, agricultural, and rainfall data, and to establish a service that addressed both questions of agricultural ecology and agricultural meteorology in the interest of farmers, in particular the owners of large plantations. As argued by Michitake Aso, plantation agriculture was key to promoting ecological studies in Indochina, both in terms of the plant-environment relationship (as in Carton's case) and the human-environment relationship (for instance, regarding diseases which affected plantation workers, such as malaria).[47]

When he prepared the 1926 report on his service, Carton stated that Indochina did not yet have an independent agro-meteorological service, because it was "un pays tropical de colonisation relativemente récente" (a tropical country of comparatively recent colonisation). Yet, the situation was changing rapidly, because the French colonial administration wanted to make the most of the natural resources available in the area. Technical and scientific services for agriculture were expanding and Indochina was entering into a period of unprecedent economic growth, with more and more requests for land concessions and a constant increase in the amount of cultivated land.[48] Tropical crops such as coffee, tea, rice, and *hevea* prospered in Indochina's climate, and Carton's agro-meteorological service regularly collected observations on these plants for meteorological and ecological studies.[49]

Carton's Bureau was based at the Central Meteorological Observatory in Phu Lien, and Indochina's agro-meteorology service was run cooperatively by the colonial administration's agricultural and meteorological departments. The Bureau was also in regular contact with the General Inspectorate for Agriculture, Breeding, and Forestry, the directors of the agricultural stations, and the plantation owners.[50] By the early 1930s, the service was well-established and Carton could prepare a comprehensive report on its current state and plans for further development.[51] The service relied on a complex network of meteorological, climatological, and pluviometric stations.[52] Meteorological and climatological stations, which required trained staff and consistent instrumentation, were distributed only in key areas, such as the coast of the Gulf of Tonkin, the coast of the South China Sea, the Mekong River and the Annamese Mountains (Fig. 2). On the contrary, the pluviometric stations were distributed all over Indochina because they were comparatively easy to run and maintain, as they only required a rain gauge (Fig. 3). Yet, the reason for the proliferation of the pluviometric stations was not merely the modest investment required in establishing them. Rainfall data were extremely

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[46] Paul Carton, *Cours de climatologie et d'écologie* (Hanoi: Gouvernement général de l'Indochine, Inspection générale de l'agriculture et de l'élevage, École supérieure d'agriculture de l'Indochine, 1938).

[47] Michitake Aso, *Rubber and the Making of Vietnam: An Ecological History, 1897–1975* (Chapel Hill: The University of North Carolina Press, 2018), 131.

[48] Organisation Météorologique Internationale, *Commission de Météorologie Agricole: Procès verbaux de la 2ième réunion, Zurich, 1926*, 46–51.

[49] Paul Carton, *La météorologie et ses applications dans les pays tropicaux* (Hanoi: Imprimerie d'Extrême-Orient, 1930).

[50] Organisation Météorologique Internationale, *Commission de Meteorologie Agricole: Procès verbaux des séances de Munich, 19–21 Septembre 1932*, 24.

[51] Carton, *La météorologie et ses applications dans les pays tropicaux*.

[52] The description of Indochina's agro-meteorological service is extracted from Carton (Carton, *La météorologie agricole en Indochine*; Organisation Météorologique Internationale, *Commission de Meteorologie Agricole: Procès verbaux des séances de Munich, 19–21 Septembre 1932*, 112–16.).

precious for planters, because they gave indications of the best times to sow and harvest, as water availability was important for the growth of tropical crops such as rice. Rainfall distribution was also key to agro-meteorological and agro-ecological investigations because it was one of the factors that most influenced Indochina's climate and Carton devoted detailed studies to this topic.[53]

Indochina's meteorological stations were mainly staffed by personnel of the meteorological services, who gathered data for weather forecasts. According to the number of daily observations taken (five or three), the stations were divided into first order stations and second order stations. There were also a few semaphoric stations which monitored ship traffic and collected meteorological observations. To facilitate communications, telegraphs connected all the meteorological stations to the Central Observatory, where the weather maps were prepared.

The climatological stations were staffed mainly by personnel of the agricultural services, who gathered data specific to agro-meteorological and agro-ecological studies. The agricultural services staff collected detailed qualitative and quantitative observations on the main crops by following the requests codified in the forms specifically designed by Carton's service.[54] The climatological stations were not directly connected by telegraph to the Central Observatory and usually only mailed a monthly summary of their data to the observatory.

Alongside the official climatological stations sponsored by the French colonial government, the Pasteur Institute also supported climatological stations on plantations, as agro-meteorological information helped plantation managers to plan their operations more efficiently. Carton's Bureau collected, analysed, and published the combined agricultural and meteorological data. The Bureau also acted as a central repository for literature on climatology and agricultural meteorology for tropical crops. In association with the colonial services and the companies that managed the plantations, Carton also organised experimental work in agro-meteorology and agro-ecology and published the results of these studies.

Meteorological and climatological stations in French Indochina had slightly different equipment, because, as mentioned, they served different purposes. Only meteorological stations had mercury barometers as pressure was a key variable for preparing weather charts, while only climatological stations gathered data on the air temperature above the soil, because this was a crucial factor in microclimatological studies on the correlation between plant growth and weather conditions. The meteorological instruments and the instrument shelters used in Indochina were in many cases modified versions of European ones, although in some instances—for example, the weather vane adopted by the data collecting stations—they were designed *ad hoc* by the staff of the Central Observatory.

Many of the meteorological instruments used by the Indochina service were self-recording because there was not enough staff to attend regularly to the instruments and take the readings at the required times. The problem posed by the insufficient staff was also heightened by the rapid expansion of the Indochinese agro-meteorological service, which grew from fewer than 30 stations in 1925–1926 to a complex network of over 500 stations six years later. In 1932, 36 of these stations were meteorological, 62 climatological, and 437 pluviometric. The growth of the service was prompted by an increase in the number of plantations and the consequent requests of support from plantation owners, as well as by the

[53] Carton, *Contribution à l'étude du régime pluviométrique de l'Indochine*.

[54] The forms can be found in Carton, *La météorologie et ses applications dans les pays tropicaux*.

development of aviation and the necessity for more detailed and reliable weather forecasts for flights in Indochina.

The agro-meteorological service's stations were manned by local and European staff working for the agricultural, forestry, and meteorological services of the French colonial administration. In addition, missionaries, members of the Pasteur Institute in Indochina, representatives of the Indochinese sugar industry, staff of the Michelin company (which owned extensive *hevea* plantations), and staff of local hospitals contributed to collect weather and crop data.[55] We do not know anything in detail about the local staff, except that they were trained in the institutions established by the French colonial government, such as the Indochina Central Observatory, before beginning fieldwork. In his scientific publications, Carton does not provide information on local meteorological and agricultural practices, because, as many of his contemporaries, he did not pay much attention to local knowledge.[56] Yet, his agro-meteorological service could not have existed without the native staff manning meteorological, climatological, and pluviometric stations. Furthermore, Carton and colleagues could not ignore local agricultural practices, when the control of crop pests, such as rice parasites, was at stake.[57]

The agro-meteorological service in Indochina pursued research in agricultural ecology by investigating the relationship between the crops of economic interest to the French colonisers and the local environment (soil type, humidity, solar radiation, etc.). Carton provided a very specific reason for working on ecological as well as meteorological issues: he argued that in the tropics, the quality of weather forecasts was limited by the small network of data collecting stations and by the scarce staff available for data analysis. The weather bulletins produced, therefore, might be suitable for aviation and navigation, but were not detailed enough for agriculture, where the only valuable forecasts were those that could give precise indications to farmers about the best time to sow and harvest, and that aided in the management of the farming operations.[58]

For this reason, Carton advocated the ecological approach, where the relationship between weather factors and plant growth was investigated according to the long-term perspective of the climate, not the short-term perspective of the weather. Carton conceived of climate as an average of meteorological factors, such as temperature, humidity, solar radiation, and rainfall, and he saw the main task of agricultural ecology as assisting in "adapting crops to the climate, through the choice of new varieties and of judiciously designed cultivation methods applied at the most appropriate times".[59,60] Carton's agro-ecological choice was motivated by the practical use of agro-meteorological knowledge in French Indochina. To transform the recently colonised area into a profitable enterprise, the French colonisers had to understand what crops could thrive in the area and how their productivity could be enhanced

[55] A comprehensive list of stations and their staff can be found in the 1932 Proceedings of the IMO Commission for Agricultural Meteorology (Organisation Météorologique Internationale, *Commission de Meteorologie Agricole: Procès verbaux des Séances de Munich, 19–21 Septembre 1932*, 113–14.).

[56] Aso, *Rubber and the Making of Vietnam*, 147.

[57] F. Bugnicourt, "Principaux cryptogames parasites du riz en Indochine et traitement à leur opposer," *Bulletin économique de l'Indochine* (1934): 1188.

[58] The U. S. Weather Bureau recognised the importance of local weather forecasts and produced specific bulletins for each cultural district (Organisation Météorologique Internationale, *Commission de Météorologie Agricole: Procès verbaux de la 2ième réunion, Zurich, 1926*, 42–44). The most famous activity of this kind is probably California's citrus fruit frost service (Floyd D. Young, *Frost and the Prevention of Damage by It* (Washington, D. C.: U.S. Department of Agriculture, 1920)).

[59] Original text in French: "adapter les cultures au climat, par le choix des variétés nouvelles et par des méthodes de culture judicieusement conçues et appliquées aux époques les plus convenables".

[60] Carton, *La météorologie agricole en Indochine*, 7.

by exploiting Indochina's environmental conditions. As Aso argued, ecology was a key asset in establishing *hevea* plantations in Indochina, but more generally it supported the production of agricultural commodities such as tea, coffee, and rice.[61]

Carton's description of the key aspects of agricultural ecology and its economic value is indebted to Girolamo Azzi's theories, but Carton's Bureau constantly worked to adapt agro-meteorological instruments and theories developed in Europe to Indochina's climate.[62] This was not a small task, because the scientific knowledge discussed in the Western circles of which Carton was a member had been produced in environmental conditions completely different from those of Indochina. For instance, when Carton opened Indochina's first forestry station, which was located at Trang-Bôm, in the south of the country, he was inspired by the work done in Swedish and French forests, but the problems he had to deal with were completely different from those of the studies he referred to. The fluctuations in temperature, humidity, and evaporation that created Indochina's forest microclimate and the causes of soil acidification in the French colony were very different from those in Europe. Swedish and French studies provided suggestions, but Carton could only approach the problem by testing and collecting local data in order to understand what observations were meaningful and how they could be analysed and interpreted. As in forestry, also in agriculture theories were imported from the West, but they could only be valuable, after being tried and tested on Indochinese soil and radically modified to account for the local climate and its influence on plant growth.

In turn, the results of these investigations attracted interest in Western scientific circles, which did not have first-hand experience of environmental conditions in the European colonies, but which assisted in the exploitation of the colonies' agricultural and forestry resources. Indochina was primarily an economic asset for France, and associations like the Paris-based Association Colonies-Sciences (ACS) ensured that Carton's work in agricultural ecology found an audience in the homeland, where meteorologists and agronomists were not so receptive of ecological thinking in the 1920s.[63] During the interwar years, the ACS, which was supported by banks (in particular, the Bank of Indochina) and by large corporations, was the main association that brought together scientists, colonial administrators, and economists interested in developing the French colonies. The ACS promoted scientific studies in the colonies and circulated the resultant technical knowledge within the French political and economic circles in charge of the colonial administration.[64] There is, therefore, scope in the concluding section of the paper for a reflection on the exchange of meteorological knowledge between East and West, and for a discussion of the role that international bodies, such as the IMO Commission for Agricultural Meteorology, had in this exchange.

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[61] Aso, *Rubber and the Making of Vietnam*.

[62] Carton, *La météorologie et ses applications dans les pays tropicaux*.

[63] Michitake Aso, 'How Nature Works: Experts, Ecology, and Rubber Plantations in Colonial Southeast Asia, 1919–1939," in *Comparing Apples, Oranges, and Cotton: Environmental Histories of the Plantations*, ed. Frank Uekotter (New York: Campus Verlag, 2014).

[64] Bonneuil, *Des savants pour l'Empire*, chapter II.

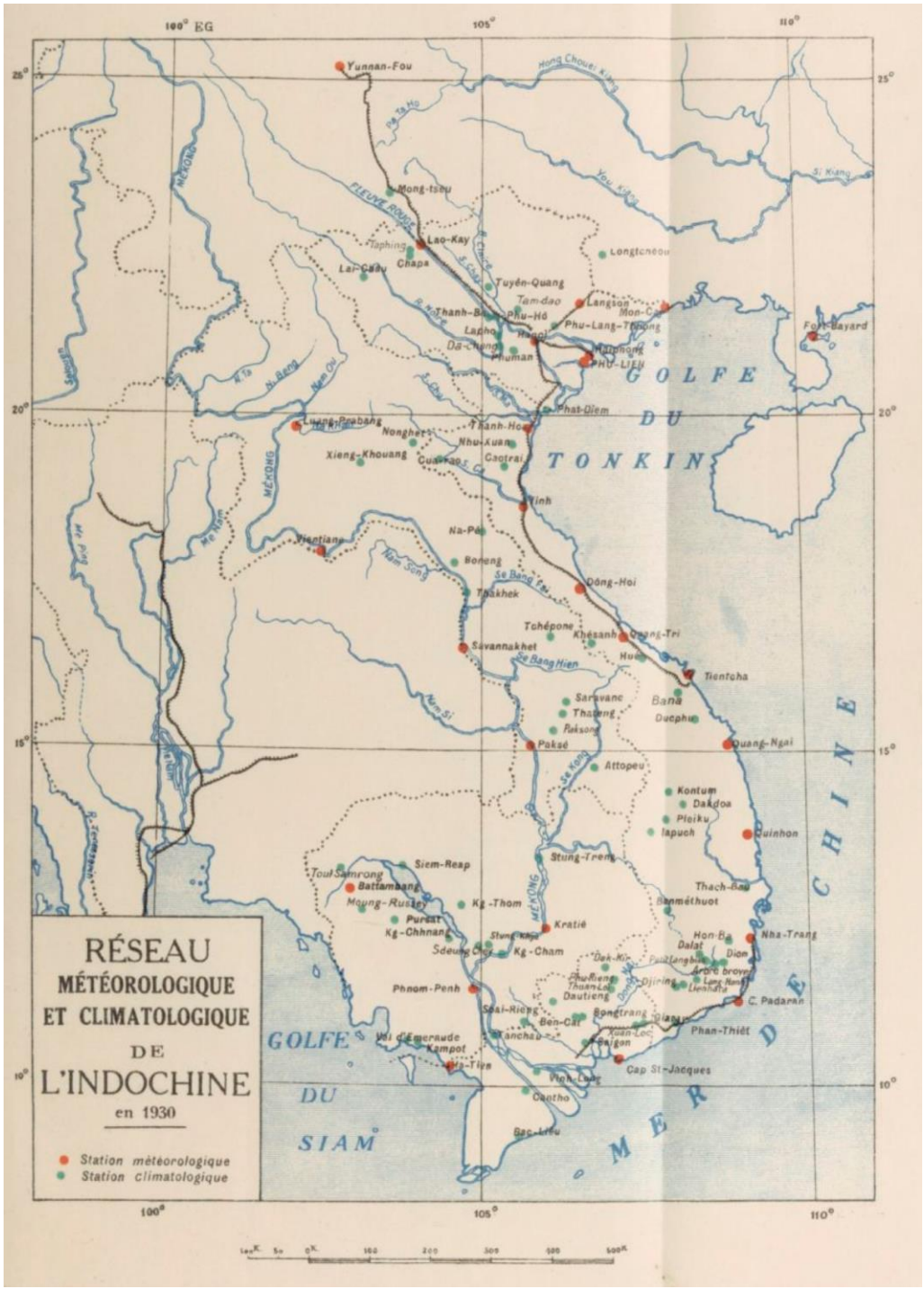

Fig. 2. Map displaying meteorological and climatological stations in French Indochina in 1930. The image is extracted from a digitised copy of Paul Carton, *La météorologie agricole en Indochine* (Hanoi: Imprimerie d'Extrême-Orient, 1930). (Source: gallica.BnF.fr)

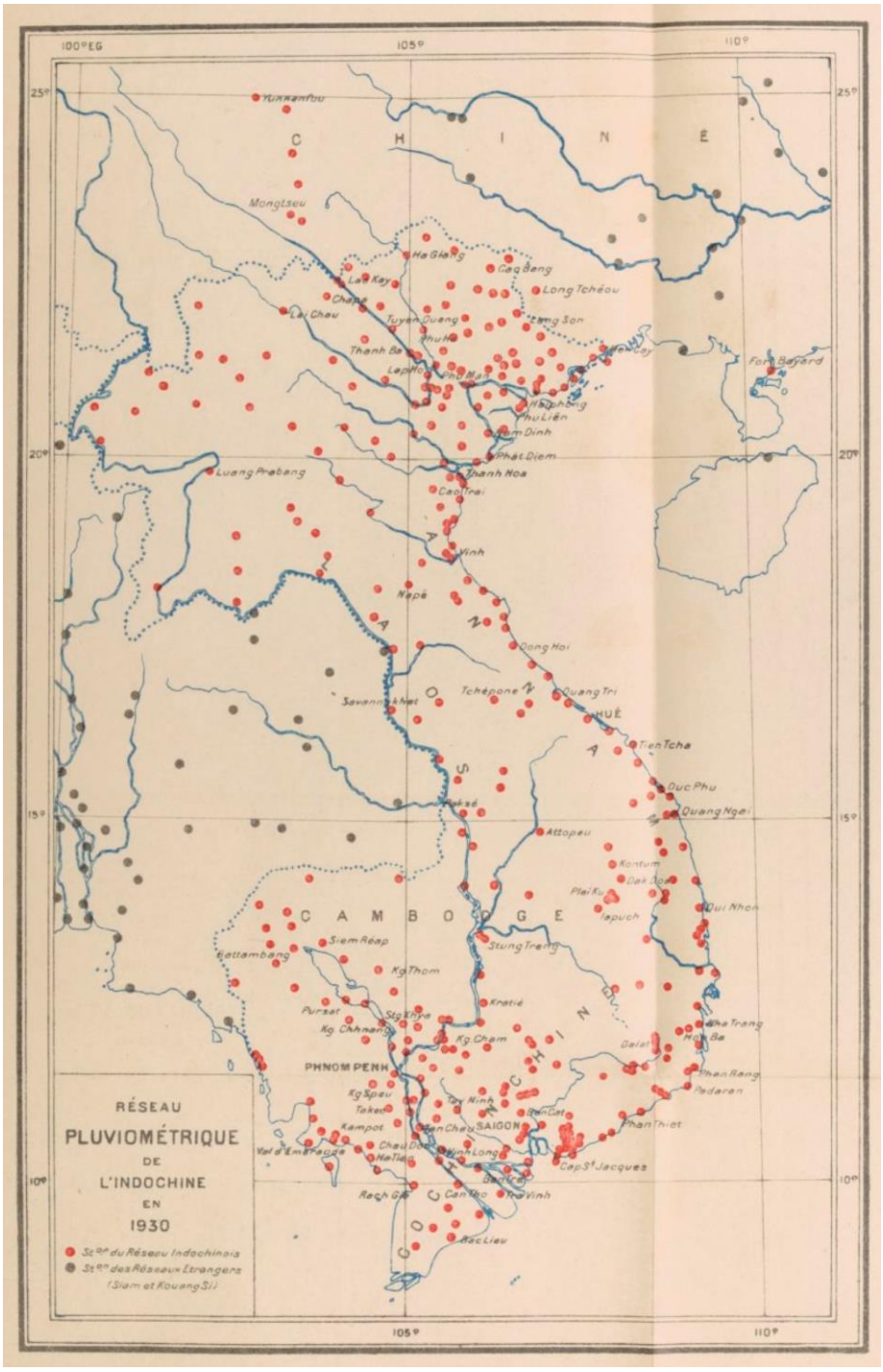

Fig. 3. Map displaying the network of pluviometric stations in French Indochina in 1930. The image is extracted from a digitised copy of Paul Carton, *La météorologie agricole en Indochine* (Hanoi: Imprimerie d'Extrême-Orient, 1930). (Source: gallica.BnF.fr)

Agro-Meteorological Knowledge Between East and West

As argued by Fleming, Janković, and Coen, histories of weather and climate must take into account both global and local perspectives.[65] On the one hand, meteorology, as practiced on an international scale by the IMO, can be considered a case of "infrastructural globalism".[66] On the other hand, though, "surveillance, control, and domination" required meteorological and climatological knowledge produced locally, especially in the European colonisation of the tropics.[67] The coexistence of global and local factors is evident in the networks of knowledge exchange built by the IMO Commission for Agricultural Meteorology and in the way meteorological and climatological information circulated through these networks. The IMO commission's success as an international body depended on the agro-meteorological work done locally by its members and on their willingness to share their knowledge in an international context. Without this interplay of global and local knowledge, first-hand information on tropical crops would not have reached European scientific circles and worldwide observational and experimental schemes in agricultural meteorology would not have been established.

The agro-meteorological service in French Indochina I examined in my paper offers a clear example of this interplay of global and local perspectives in meteorology, with particular reference to the circulation of weather and climate information between East and West. It is true that most of the meteorological instruments employed in Indochina were manufactured in France, that the key people who managed the agro-meteorological service were members of the French colonial establishment trained in European institutions, and that the service was run according to Western standards; yet, it would be misleading to conclude that the exchange of agro-meteorological knowledge was one-way only, from Europe to Indochina. To succeed in its mission—that is, to support colonial agriculture and in particular the development of large and profitable plantations for European companies—Carton's agro-meteorological service had to modify meteorological instruments and make them suitable for tropical conditions. Carton also had to adapt Western ideas on agricultural meteorology, developed where weather services had been at work for decades and tested only on crops grown in temperate areas, to the specificities of a newly colonised region, Indochina, where infrastructures for collecting and communicating weather data were still limited and where tropical crops were cultivated.

In response to the limitations of weather forecasting in Indochina, Carton made agricultural ecology an integral part of his agro-meteorological service and shifted the focus from preparing weather bulletins, which was not an achievable goal in the recently colonised area, to mapping and understanding the local climate. The starting point for Carton's investigations in agricultural ecology were the theories developed by the Italian Girolamo Azzi, who studied wheat extensively, but these theories could not be transposed verbatim to the study of tropical crops. Carton and his fellow colonial officers had to gather data on the response of plant varieties to Indochina's climate and organise experimental work on tropical crops in collaboration with local plantation owners. This local research was a necessary step for gathering climatological and microclimatological knowledge which could be useful in the successful cultivation of crops profitable for the French colonisers. Yet, Carton's work did not remain confined to the local domain of Indochina. The scientific experience gained from

[65] James R. Fleming, Vladimir Janković, and Deborah R. Coen, eds., *Intimate Universality: Local and Global Themes in the History of Weather and Climate* (Sagamore Beach: Science History Publications, 2006).

[66] Edwards, "Meteorology as Infrastructural Globalism."

[67] Fleming, Janković, and Coen, *Intimate Universality*, xi.

tropical crops flowed back to Europe through Carton's extensive correspondence with the presidents of the IMO commission and enabled the commission to include tropical crops in its debates. Moreover, as pointed out before, Carton's research on agricultural ecology was brought to the attention of French agronomists and meteorologists, through associations like the ACS. It would be simplistic, therefore, to envision the IMO Commission for Agricultural Meteorology as an organisation interested only in exporting knowledge from Europe to its colonies. The commission was also eager to learn from the work done by the non-European members and recognised that tropical crops were an essential part of the global economy in the first half of the twentieth century.

It would be very interesting to extend the present investigation beyond Indochina and examine how the work of the IMO Commission for Agricultural Meteorology benefitted from the contributions of other members based outside of Europe, especially in the East. The Japanese meteorologist Takematsu Okada was a member of the IMO commission for several years and, in one case, he attended a meeting of the commission in person. The Dutch meteorologist Cornelis Braak, the commission's last president before World War II, had worked in the Dutch East Indies before taking up a position at the Royal Meteorological Observatory in de Bilt. Unfortunately, neither Okada nor Braak were as keen correspondents as Carton. Their contributions to the IMO commission cannot be reconstructed in detail from the *Proceedings* that today are the only resource available to understand how the organisation built its networks of knowledge exchange.[68] Nor there are specific studies on agricultural meteorology in the East that can be accessed by an international audience and can be connected to the information available on the IMO commission. One can only hope that more case studies on the development of meteorology and climatology and their practical applications outside of Europe and the United States will increase in coming years, inspired by the same agenda that has motivated this special issue. Hand-in-hand with the increased interest in writing global histories, the historiography of meteorology, and of the atmospheric sciences more generally, can significantly grow and develop.

Acknowledgments

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[68] The World Meteorological Organisation does not have any archival holdings related to the work of the IMO Commission for Agricultural Meteorology. Occasionally, correspondence related to the commission emerges among the private papers of its members (e.g. the R. A. Fisher Papers held in the archives of Rothamsted Research, ref. STATS 6.3), but this correspondence is fragmentary and does not allow us to systematically reconstruct the IMO commission's work.