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Kwa, C.

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CHUNGLIN KWA*

The Visual Grasp of the Fragmented Landscape: Plant Geographers vs. Plant Sociologists

ABSTRACT

Between 1925 and 1980, landscape ecology underwent important changes through the gradual imposition of the view from above, through the uses of aerial photography. A new concept emerged, "the smallest unit of landscape," also called ecotope and land unit, expressing a direct visual grasp of the landscape. This article compares the view from above as introduced and promoted by geographers Carl Troll and Isaak Zonneveld, with its (problematic) history vis-à-vis a school of ecology, i.e., plant sociology, led by Josias Braun-Blanquet and Reinhold Tüxen. This school's internal struggles with balancing the physiognomic gaze (at the ground) and numerical methods are discussed. In comparison, the geographers based themselves on the mechanical objectivity of standardized aerial surveys, whereas the plant sociologists relied on their subjective expert judgment of plant recognition together with the structural objectivity of their numerical methods. An important communality of both schools was their inductive building of a landscape from its constituent landscape fragments. Landscape fragments were identified through abstraction and categorization, emanating from a taxonomical style of science.

KEY WORDS: Carl Troll, view from above, aerial photography, Josias Braun-Blanquet, Reinhart Tüxen, visualization, plant sociology, I. S. Zonneveld

* Amsterdam Institute for Social Science Research, University of Amsterdam, P.O. Box 15718, 1001 NE Amsterdam, Netherlands, c.l.kwa@uva.nl.

The following abbreviations are used: ITC, International Training Centre for Aerial Survey, Enschedé, Netherlands; Ztschr. Ges. Erdk. Berlin, Zeitschrift der Gesellschaft für Erdkunde zu Berlin.

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INTRODUCTION

In 1928, German geographer Carl Troll (1899–1975) discovered the value of the "view from above" while engaged in a three-year South American expedition. While travelling by aircraft, he saw a landscape, below, that he had investigated on the ground. Henceforward, Troll would campaign for a new landscape geography based on the interpretation of aerial photographs, and he became a successful spokesman for the new field (also called landscape ecology) in the decades after World War II. As vice chair and chair of the International Geographical Union from 1956 to 1968, his influence extended well beyond Germany.

Aerial pictures give us a rendering of the typically patchy landscape we are now all familiar with when looking down from a passenger aircraft. In 1928, they were on the forefront of science. First applied in World War I, for discovering the location of the enemy's trenches and similar exploits, their application for science had only been comparatively recent. Aerial pictures produced a landscape as had been previously captured only occasionally using balloons: either an oblique view with the horizon high up, or the more common view, which is focused vertically downward, and showing no horizon at all.[1] Troll considered the parcels to be the "smallest units of landscape."

In an adjacent discipline, plant sociology, a view from the air was all but ignored. Nonetheless, plant sociologists had also arrived at conceiving a patchy vegetational cover, by entirely different means. Plant sociology, also called phytosociology, is a continental European school of plant ecology. Its practitioners count plants, or estimate their numbers, and perform computations to arrange plants into groups. As such, the plant sociologists did have a use for the visual inspection of the vegetational cover, although with restrictions.[2] Troll

1. Peder Anker, *Imperial Ecology: Environmental Order in the British Empire* (Cambridge, MA: Harvard University Press, 2001); Sebastian Grevsmühl, *La terre vue d'en haut: L'invention de l'environnement global* (Paris: Le Seuil, 2014); Jeanne Haffner, *The View from Above: The Science of Social Space* (Cambridge, MA: The MIT Press, 2013). On Troll, see Chunglin Kwa, "Painting and Photographing Landscapes: Pictorial Conventions and Gestalts," *Configurations* 16 (2008): 57–75; and Sonja Dümpelmann, *Flights of Imagination: Aviation, Landscape, Design* (Charlottesville, VA: University of Virginia Press, 2014). I thank an anonymous referee of HSNS for drawing my attention to Dümpelmann's book.

2. General histories of ecology contain only rather brief of accounts of phytosociology, even when acknowledging its importance to ecology. See Robert P. McIntosh, *The Background of Ecology: Concept and Theory* (Cambridge: Cambridge University Press, 1985); Astrid Schwarz and Kurt Jax, "Early Ecology in the German-Speaking World Through WWII," in *Ecology Revisited:*

criticized the plant sociologists rather sharply for not taking the visual approach to the landscape seriously.

This article will compare the visual approaches employed by landscape geographers and phytosociologists on their research subject roughly between 1925 and 1980. We will follow Troll's theoretical development of the view from the air, and trace his career to investigate the uses to which it was put. We will also examine the history of the phytosociological school, its theory of how plants associate themselves in groups, and the development of the methodology for identifying the plant groups. The plant sociologists made use of Troll's work (and vice versa), but they remained silent about his critique of their methodology. A discussion of the work of Isaak ("Ies") Zonneveld (1924–2017), a Dutch geographer, will form the third part of this article. Zonneveld contributed to the field of landscape geography by helping to make aerial photography a world-wide activity. A follower of Troll's, he tried to close the gap between plant sociologists and aerial view photography,

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Reflecting on Concepts, Advancing Science, ed. Schwarz and Jax (Dordrecht: Springer, 2011), 231–75; Jean-Paul Déléage, *Histoire de l'écologie: Une science de l'homme et de la nature* (Paris: La découverte, 1991); Jean-Marc Drouin, *Réinventer la nature: L'écologie et son histoire* (Paris: Desclée de Brouwer, 1991); Pascal Acot, *Histoire de l'écologie* (Paris: Presses universitaires de France, 1994); Patrick Matagne, "The French Tradition in Ecology: 1820–1950," in *Ecology Revisited: Reflecting on Concepts, Advancing Science*, ed. Astrid Schwarz and Kurt Jax (Dordrecht: Springer, 2011), 287–306. Kaat Schulte Fischedick, "Practices and Pluralism: A Socio-Historical Analysis of Early Vegetation Science, 1900–1950" (PhD dissertation, University of Amsterdam, 1995), while not giving a general history, contains many valuable materials and analyses of phytosociology. Henny van der Windt, *En dan, wat is natuur nog in dit land? Natuurbescherming in Nederland*, *1880–1990* (Meppel/Amsterdam: Boom, 1995), discusses the influence of phytosociologist Victor Westhoff on nature conservation in the Netherlands.There are a good number of practitioners' histories, sometimes contained in scientific contributions to the field, offering valuable facts, most often of biographical and institutional nature: Helmut Dierschke, *Pflanzensoziologie* (Stuttgart: Eugen Ulmer), 1994, see esp. 17–30, 254–55; H. Dierschke, "History of phytosociology in Europe, especially in the last 50 years," in *Proceedings IAVS Symposium*, 2000, ed. P. S. White, L. Mucina, and J. Lepš, 9–13; H. Dierschke, "Developments and Tasks of Syntaxonomy: The Status at the End of the 20th Century and Scopes for the Future," *Ecohabitat (JISE Research)* 17 (2010): 109–37; Victor Westhoff, "Phytosociology in the Netherlands: History, present state, future," in *The Study of Vegetation*, ed. M.J.A. Werger (The Hague: Junk, 1979), 81–121; V. Westhoff, J.H.J. Schaminée, and K.V. Sýkora, "De geschiedenis van de plantensociologie in Nederland," in *De vegetatie van Nederland, deel 1*, ed. J.H.J. Schaminée A.H.F. Stortelder and V. Westhoff (Uppsala/Leiden: Opulus Press, 1995), 33–52; Victor Westhof and Joop Schaminée, "Historie," in *100 jaar op de knieën. De geschiedenis van de plantensociologie in Nederland*, ed. J.H.J. Schaminée and R. van 't Veer (Noordwolde: Opulus Press, 2000), 54–127; J.H.J. Schaminée and J.A.M. Janssen, eds., *Schatten voor de natuur: Achtergronden, inventaris en toepassingen van de Landelijke Vegetatie Databank* (Utrecht: KNNV Uitgeverij, 2006).

but his attempts to reconcile the former to the employment of the latter were largely ignored.

Troll promoted the idea of the patchy look of the landscape with much enthusiasm. It could be captured directly in aerial photographs, he argued. Troll could lay no claim to having discovered the new, patchy landscape all by himself, and indeed, he did not do so. He acknowledged that others had made similar discoveries independently, and in some cases somewhat earlier.[3] A host of terms had been minted to convey the idea: unit area, landscape element, *Fließe* (tiles), land unit, among others. They are now usually called "ecotopes." It was Troll who proposed this term in an attempt to impose terminological order within the nascent field of landscape ecology.[4] Troll did not shy away from claiming the invention of landscape ecology, as a term and as a field, and he claimed that the view from above yielded a true "physiognomic" apprehension of the landscape.[5]

The term "physiognomy" refers back to Alexander von Humboldt, who had argued that one could see "in a single glance" that the vegetational zones of the earth have distinct physiognomies. Each of Humboldt's zones had been unified wholes in their own way and were as such different individuals (sixteen in total). In contrast, Troll's physiognomic gaze found the landscape to be patchy, regardless of where it was viewed. Troll and others would point at the gestalt-like similarity with the traditional cultural landscape of fields, meadows, and hedgerows, which they saw as grafted on a natural landscape with a similar structure.[6] And whereas Humboldt had trusted the unaided eye, for

3. Carl Troll, *Luftbildforschung und landeskundlichen Forschung* (Wiesbaden: Franz Steiner Verlag, 1966).

4. Current uses of the term come closest to Troll's definition of the "ecotope." Hence, the attribution to Troll is historically defendable, even though a few ecologists had used the word in print before Troll did: Arthur Tansley in the United Kingdom and Josef Schmithüsen in Germany. Carl Troll, "Die geographische Landschaft und ihre Erforschung," *Studium Generale* 3 (1950): 163–81; Carl Troll, "Landscape Ecology (Geoecology) and Biogeocenology—A Terminological Study," *Geoforum* 8 (1971): 43–46.

5. Carl Troll, "Landschafsökologie," in *Pflanzensoziologie und Landschaftsökologie*, ed. Reinhold Tüxen (The Hague: Junk, 1968), 1–21; K.-F. Schreiber, "The History of Landscape Ecology in Europe," in *Changing Landscapes: An International Perspective*, ed. I. S. Zonneveld and Richard T. T. Forman, (New York: Springer, 1990), 21–34.

6. Chunglin Kwa, "Alexander von Humboldt's Invention of the Natural Landscape," *The European Legacy* 10 (2005): 149–62; Kwa, "Painting and Photographing" (ref 1). On gestalts and their visual persuasiveness, see also Omar Nasim, "Observation, working images and procedure: The 'Great Spiral' in Lord Rosse's astronomical record books and beyond" *British Journal for the History of Science* 43 (2010): 353–89.

geographers such as Troll the new technology of aerial photography redefined what "physiognomic" was. The necessary vertical or oblique direction of the camera is already mentioned. For the "smallest units of landscape" to appear on the picture, it is also crucial that scales between 1:10,000 and 1:25,000 are used, the typical scales of aerial surveys.[7]

During this period, the idea of the heterogeneity of the landscape was by no means a shared perspective among geographers and ecologists. Instead, the holistic view prevailed. Troll, himself, referred many times to the "harmony" in the landscape, although he did not quite spell out what that harmony was. Troll traced his method of making vegetation surveys somewhat loosely to Oskar Drude, geographer in the Humboldtian tradition.[8] Yet the patches do not build an obvious harmony among themselves. It is the lack of a unified whole in the pictures that characterizes the aerial photographs most. Beginning in the second half of the nineteenth century, viewers had developed tolerance for noise in pictures and the absence of a central subject.[9] The aerial photography developing after World War I was a further stage of this development.

The year 1928 was a marker date, too, in the history of plant sociology: it saw the publication of *Pflanzensoziologie* (Plant Sociology) by Josias Braun-Blanquet (1884–1980).[10] This founder textbook of the so-called Zürich-Montpellier school (named after the cities in which Braun-Blanquet had worked) went through two more editions in 1951 and 1964, and Braun-Blanquet continued to publish until at least 1975.

7. The typical gestalt of the patchy landscape disappears in both low- and high-altitude renderings. In the former individual tree crowns appear, and pictures of the land will resemble garden designs. In the latter, mountain ranges, river valleys, and coast lines become the dominant features of the landscape. We may note in passing that "smallest units of landscape" do not in fact exist. The fragmented landscape is a fractal landscape.

8. Carl Troll, "Die Landbauzonen Europas in ihrer Beziehung zur natürlichen Vegetation," *Geographische Zeitschrift* 31 (1925): 265–80; Carl Troll, "Gedanken und Bemerkungen zur Ökologischen Pflanzengeographie: Anlässlich der Neubearbeitung von Schimpers 'Pflanzengeographie auf physiologischer Grundlage' durch F.C. von Faber," *Geographische Zeitschrift* 41 (1935): 380–88. On Drude, see Malcolm Nicolson, "Humboldtian Plant Geography after Humboldt: the Link to Ecology," *British Journal for the History of Science* 29 (1996): 289–310, on 305. Drude had produced geographical maps of plant formations.

9. Jonathan Crary, *Techniques of the Observer* (Cambridge, MA: MIT Press, 1990), 125–26; Roland Barthes, *La chambre claire: note sur la photographie* (Paris: Gallimard Seuil, 1980), 44.

10. Josias Braun-Blanquet, *Pflanzensoziologie: Grundzüge der Vegetationskunde* (Berlin: Springer Verlag, 1928; 2nd ed., Vienna: Springer Verlag, 1951; 3rd ed. 1964); English translation: Josias Braun-Blanquet, *Plant Sociology: The Study of Plant Communities* (New York: McGraw-Hill, 1932).

Plant sociologists were unaided by photography.[11] The phytoecologist's is the walker's view, but he is not looking around him, as hikers usually do. Instead, his gaze is the typical botanist's, directed to the ground a few inches in front of his feet. Or bent down: one phytosociological chronicle is called *A hundred years of kneeling*.[12] The resulting picture of the vegetational cover of the land is obviously of a different scale than the landscape of the geographer. But the phytosociologist also "sees" a patchy vegetational cover. Scale differences were not the problem dividing the geographers and phytosociologists, as they thought that to be bridgeable. Their rivalry was about visual methodology. To be able to see the plant sociologists' parcelation requires advanced botanical knowledge. The visual part is a stepping stone only to the next stage: corroborating what one sees by making lists of plants and sorting them through tables. Braun-Blanquet's approach was adopted around 1935 by Reinhold Tüxen (1899–1980) in Germany. Tüxen oversaw a systematization of phytosociological data interpretation. This final stage in the identification of plant associations is a computation carried out on the tables. It is an intuitive arithmetic, in which the data are sorted through a manipulation of the tables in several steps. At the end of the computational process, the visual aspect has all but disappeared. Eddy van der Maarel, a Dutch ecologist who transferred early in his career to Uppsala, Sweden, did much to give the arithmetic a sound statistical footing several decades later.

Troll had argued against the phytosociologists, noting that, although they professed a physiognomic approach to the vegetation, they were not physiognomic enough. It was Zonneveld who brought out what the epistemic difference was between geographers such as Troll and himself, and the plant sociologists. He contrasted the "subjective" identification of phytosociological units with the "objective" aerial photographs. It is highly likely that Zonneveld was taken by the "mechanical objectivity" of standardized aerial surveys. The plant sociologists, on their part, relied on trained expert judgment of plant recognition together with what may be called the "structural objectivity" of numerical methods.[13]

11. Many other field ecologists of different persuasions were not convinced that photography offered enough discriminating power in the field. See Robert Kohler, *Landscapes and Labscapes* (Chicago: University of Chicago Press, 2002), on 125–27.

12. Schaminée and Van 't Veer, *Op de knieën* (ref. 2).

13. Lorraine Daston and Peter Galison, *Objectivity* (Cambridge, MA: The MIT Press, 2007): on mechanical objectivity see 115–90, on trained judgment see 309–21, on structural objectivity see 253–73.

CARL TROLL AND THE "VIEW FROM ABOVE"

Troll's discovery of the value of the view from the air was made in South America. He had embarked on a long voyage through the Andes from 1926 until 1929, 40 months in total, on a grant from the Notgemeinschaft der Deutschen Wissenschaft, shortly after his Habilitation in geography had been accepted. (His PhD, obtained at the age of 22, was in botany.) He travelled by foot and by mule as one of two scientific members of a larger German-Austrian alpinist team. High up in Bolivia, in the Cordillera Real, Troll engaged in glacier research. He measured the movement of glaciers with photogrammetric equipment, and reconstructed with the help of these and other measurements the geological past of the Andes. But his core specialty was vegetational mapping.[14]

After spending time in the mountains, Troll also travelled by canoe to investigate the vegetational cover of the coastal areas of Panama, Ecuador, and Colombia. During the last months of his stay, he flew above the region in aircraft provided by the German-Colombian Air Transport Society (SCADTA), then active in the region as a commercial airliner. Troll investigated for SCADTA the possibilities of extending their airliner network. From the air, Troll could discern "with great clarity" (*mit grösster Deutlichkeit*) the very same vegetational units he had identified from the canoe.[15] SCADTA appears not to have been active in aerial surveying and neither did Troll take pictures. But the value of aerial surveys had become evident to him.

Upon his return from South America, Troll was offered a professorship (*Extraordinarius*) in colonial geography in Berlin, in 1930. He got another chance to practice the "view from above" upon joining, in the summer of 1937, the Nanga Parbat expedition in Kashmir (now in Pakistan) at the invitation of the alpinists association. It would give him national fame. The Nanga Parbat, the ninth highest mountain in the world, was known as the "fateful mountain of the Germans," the *Schicksalberg der Deutschen*, so named by the Nazi Party.[16] Willy Merkl, a German mountaineer, had tried to climb the

14. Carl Troll, "Die Cordillera Real," *Ztschr. Ges. Erdk. Berlin* (1929): 279–312; F. Monheim, "Einleitung," in Carl Troll, *Tagebücher der Reisen in Bolivien 1926/1927* (Wiesbaden: F. Steiner Verlag, 1985), 1–6, on 2.

15. Carl Troll, "Luftbildplan und ökologische Bodenförschung: Ihr zweckmässiger Einsatz für die wissenschaftliche Erforschung und praktische Erschliessung wenig bekannter Länder," *Ztschr. Ges. Erdk. Berlin* (1939): 241–98, on 278.

16. Nazi Party, Nationalsozialistische Deutsche Arbeiterpartei (NSDAP), or National-Socialist German Workers Party. The reason the German Nazi's were so interested in this region

mountain in 1932, to no avail. When, two years later, a German team tried again, Merkl perished along with three fellow team members before they reached the top. The expedition of 1937, to which Troll was added as one of two scientific members, was meant in part as an attempt to exact revenge on the mountain. On their way to the top, during a night's rest in a high-altitude camp, the seven German climbers, not including Troll, together with nine Sherpas, were buried in their sleep by an avalanche. Troll discovered the disaster the following day. The day after that, Troll himself narrowly escaped an avalanche.[17]

Troll's mission during the Nanga Parbat expedition was to complete a 1:50,000 map, which had been prepared during the 1934 expedition, with the vegetational characteristics of the region. To this end, Troll walked a network of footpaths. He investigated the relatively large areas between the footpaths with the help of binoculars—a handy visual method, aerial inspection from the ground. Apparently, it was a novel method. Troll defended it at length. Forms and colors of the vegetation were highly distinctive, the vegetational units could be identified with "certainty," as Troll writes.[18]

As in his previous vegetational mappings, the scale used by Troll was a bit too rough to achieve the level of the floristic plant units of the French-Swiss school. For this, a map with scale 1:20,000 would more suitable. Troll acknowledged that a finer-grained map than he himself had developed would be desirable to reach the French-Swiss school's level of plant associations. But, as noted above, he never went on to use the phytosociological methodologies. At various places, Troll gives lists of plants of a certain area, but these apparently do not emanate from classical *relevés*, lists of plants with estimations of their frequency drawn up at specifically circumscribed areas. His terminology smacks loosely of plant sociology.[19] He names plant societies (*Pflanzengesellschaften*), though not in the Braun-Blanquet terminology, mentions plant *Genossenschaften* (comradeships), and identifies plant *Begleiter* (companions) of

was the idea that it was the original heartland of the "Aryans." See M. Szöllösi-Janze, *Science in the Third Reich* (Oxford and New York: Berg), 2001, on 71.

17. Carl Troll, "Der Nanga Parbat als Ziel deutscher Forschung," *Ztschr. Ges. Erdk. Berlin* (1938): 1–26, on 19.

18. Carl Troll, "Das Pflanzenkleid des Nanga Parbat: Begleitworte zur Vegetationskarte der Nanga-Parba-Gruppe (Nordwest-Himalaja)," *Wissenschaftliche Veröffentlichungen des Deutschen Museum für Länderkunde zu Leipzig, Neue Folge 7* (1939): 151–93, on 151. On Troll's mapping achievements, see Friedrich-Karl Hofmeier, "Carl Troll: His footprints in physical geography," *Progress in Physical Geography* 39 (2015): 554–65, on 555.

19. Troll, "Pflanzenkleid" (ref. 18), table 24.

the "leading species" (*Leitpflanze*) in a patch of vegetation. There are a few approving references in his work to ecologists whom he apparently regarded as sources of inspiration. Most go to Oskar Drude, whose work on plant geography dated from the 1890s, and to some geographers whom Troll saw as improving upon Drude.[20]

Troll's View from Above

In a long article, published in 1939, Troll reflected at length on the possibilities of air photography, drawing on his earlier work in South America. He payed homage to earlier pioneers such as Erich Wasmund in Germany and above all to large-scale landscape studies by the British in North Rhodesia and Burma, and the Dutch in the Dutch East Indies (now Indonesia).[21]

It is primarily on the basis of such articles, and the pictures that they contain, that Troll developed the idea of the "smallest units of landscape." "With amazing clarity," wrote Troll, "can we discern the vegetational units on the aerial pictures [of Bangka, a small Indonesian island between Borneo and Sumatra] (Fig. 1). The mixed rain forests of the firm dry land, with tree crowns of unequal size and unequal color, distinguish themselves sharply from the uniform tidal forests."[22] Troll had not visited Banka himself. Yet, the pictures were entirely persuasive to him, and he felt confident of their interpretation. Here and at other places, Troll argued that through air photography one can discover the mosaic-like structure of the land. He insisted many times that landscape units have clear boundaries. Such a view is the view of the scientist who is both soil expert and vegetational scientist, and who discerns the units immediately. From above, it is the vegetation that is visible, but the vegetation is an expression of the soil. The units of the landscape are units of the natural

20. Theodor H. Engelbrecht and Rudolf Scharfetter; the latter's view on how various plant societies build "vegetational complexes" in a spatial landscape manner is mentioned with approval. See Troll, "Die Landbauzonen Europas" (ref. 8), 280; Troll, "Pflanzenkleid" (ref. 18), 152.

21. Troll, "Luftbildplan" (ref. 15). On Wasmund, see Astrid Schwarz, "Ikonische Ökologie," in *Landschaftsökologie: Grundlagen, Methoden, Anwendungen* (Bayerische Akademie für Naturschutz und Landschaftspflege, 2011), 95–101.

22. "Auf den Luftbildern . . . kann man mit einer erstaunlicher Klarheit die Bestände unterscheiden. Die gemischten Regenwälder des festen, trockenen Landes mit ihren ungleich grossen und ungleich getönten Baumkronen heben sich scharf ab gegen die einförmig zusammengesetzsten Gezeitenwälder"; Troll, "Luftbildplan" (ref. 15), 279. Troll quotes from A. Kint, "De luchtfoto en de topografische terreingesteldheid in de mangrove," *De tropische natuur* 23 (1934): 173–89 (article dated Jul 1935).

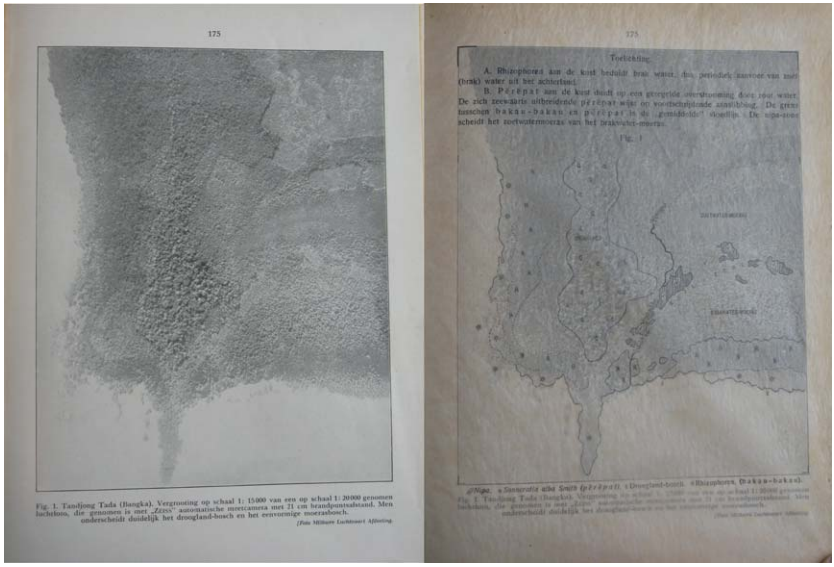

FIGURE 1. A picture of a mangrove forest adjacent to a dry land forest, with and without the diagrammatic overlay. Source: A. Kint, "De luchtfoto en de topografische terreingesteldheid in de mangrove," *De tropische natuur* 23 (1934): 173–89.

landscape, not the cultured landscape. Yet, they resemble each other in pattern and size, and this is mostly because the natural units "shine through" in the cultured landscape.[23]

The author of the original article on the Banka mangrove forests had included transparent sheets with a diagrammatic rendering of the photographs, such that they could be placed on top of the photographs. In his dicussion of the pictures, Troll does not refer to them, even though he made use of the same ancillary tool in some of his own articles and books. The use of the diagrams never became a standard practice, either on transparents or as stand-alone inserts. Apparently, the ideal and typical abstractions that diagrams provide were not really needed by the geographers. The rather rudimentary way in which the diagrams were in fact executed suggests they were an extension of the captions, crawling into the photograph.[24] However, for different audiences and purposes, diagrams were made in the form of maps. But althoughTroll

23. Troll, "Luftbildplan" (ref. 15), 251, and figure 18 on picture-page 10.

24. It is different in other fields, as shown by Sarah de Rijcke, "Light tries the Expert Eye: The Introduction of Photography in Nineteenth-Century Macroscopic Neuroanatomy," *Journal of the History of the Neurosciences* 17 (2008): 349–66, and by Michael Lynch, "The externalized retina: Selection and mathematization in the visual documentation of objects in the life sciences,"

praised the topographical maps and vegetational charts made by the Dutch on the basis of the aerial photographs, he insisted that they could not replace the photographs. For decisions such as where to build roads, one would be well advised to refer to the photographs and not to the maps, Troll said.

Troll suggests in the quote above that the Banka photographs are directly readable. Yet he explains the pictures at length, in geographical and botanical detail, including background knowledge to which he had access. This helps us realize that pictures do not explain themselves. Pictures cannot point at some reality out there, without that reality being embedded in textual interpretation. We need words and the concepts expressed in them to tie pictures to the objects they represent, as Walter Benjamin observed. "The naked image has no referent," Bruno Latour said in the same vein.[25] What, then, made Troll so confident that the view from above, by itself, yielded the true "physiognomic" representation of the landscape? We have alluded, above, to the gestalt-like similarity between aerial photographs of the landscape and the typical patterns of traditional cultured landscapes. The views of the latter were culturally available in a number of ways; painted panoramas with a vantage point as if viewed from a bell tower are one example.[26] Pictures, therefore, may have a referent in other pictures, assuming the role of visual metaphors.

Troll's Colonial Project

Troll had been spending the full academic year 1933–1934 on a voyage through Africa, beginning in Eritrea, then an Italian colony, and ending at the Cape. He passed though Tanganyika, a former German colony that was currently under British rule under a League of Nations mandate. He measured a few glaciers there and did lots of vegetational mapping. Troll was offered a second

in *Representation in Scientific Practice*, ed. M. Lynch and Steve Woolgar (Cambridge, MA: The MIT Press, 1990), 153–86.

25. Walter Benjamin, "Über die Fläche des unfarbigen Bilderbuches," *Gesammelte Schriften VI* (Frankfurt: Suhrkamp, 1985), 112–13; Walter Benjamin, "Kleine Geschichte der Photographie," *Gesammelte Schriften II, 1* (Frankfurt: Suhrkamp, 1974), 368–85, on 385; see also Georges Didi-Huberman, *Quand les images prennent position: L'oeil de l'histoire I* (Paris: Minuit, 2009); Lynch, "Externalized retina" (ref. 24), 163; Bernike Pasveer, "Representing or Mediating: A History and Philosophy of X-ray Images in Medecine," in *Visual Cultures of Sciences: Rethinking Representational Practices in Knowledge Building and Science Communication*, ed. Luc Pauwels (Hanover, NH: Dartmouth College Press, 2006), 41–62; Bruno Latour, *La clef de Berlin* (Paris: La Découverte, 1993), on 164.

26. Kwa, "Painting and Photographing" (ref. 1).

opportunity to visit Africa very soon after the termination of the Nanga Parbat expedition. Again starting in Eritrea, he travelled by car through Ethiopia over two months.[27] Troll did not have aerial photographs available during his trips in Africa. He would, of course, make the case for their use. When referring to extant climatological maps of Africa, he indicated how they could be vastly improved by including details on vegetation, for which aerial photographs would provide the data.[28] Troll also recommended aerial photography in a memorandum to the *Kolonialpolitische Amt* of the Nazi Party, in 1934, about the much-needed scientific foundation for colonial policy.[29]

Obviously, Troll's travels in Africa were carried out in the context of colonial policy. He reported on his African research in the *Koloniale Rundschau* (Colonial Review), the editorship of which he had taken on in 1936 (and in other scientific journals as well). On the surface, colonial relevance does not seem immediately self-evident. Germany had acquired a colonial empire late in the nineteenth century, mostly in Africa, and had lost it after World War I. Yet, an academic community in colonial studies had been built during Germany's brief colonial era, and several university chairs and positions in colonial geography survived after 1918. Troll's position in Berlin was one of these. A year after assuming it, Troll, with others, proposed a resolution to the 1931 German *Geographentag* (Geographers' Conference) in Danzig (Gdansk), expressing regret of the loss of the colonies. The resolution found broad support.[30] In 1934, in the notes of his discussions with the South African statesman Jan Smuts, Troll aired frustration about Germany's "unjust" loss of its colonies, writing that strong limitations had been imposed upon its "living space"

27. H. Lautensach, "Carl Troll—Ein Forscherleben," *Erdkunde* 13 (1959): 244–58.

28. Carl Troll, *Kolonialgeographische Forschung und das Deutsche Kolonialproblem* (Sonderdruck aus Verhandlungen und Wissenschaftliche Abhandlungen des 26. Deutschen Geographentages zu Jena 1936) (Breslau: Ferdinand Hirt, 1937), on 21; Carl Troll, "Koloniale Raumplanung in Afrika," *Das Afrikanische Kolonialproblem. Ztschr. Ges. Erdk. Berlin*, Heft 1–4 (May 1941), 1–41, on 34.

29. Hans Böhm, "Luftbildforschung. Wissenschaftliche Überwinterung—Angewandte (kriegswichtige) Forschung—Rettung eines Paradigmas," in *Kontinuität und Diskontinuität der deutschen Geographie in Umbruchphasen. Studien zur Geschichte der Geographie*, ed. U. Wardenga and I. Hönsch (Münster: Institut für Geographie der Westfälischen Wilhelms-Universität, 1995), 129–40, on 132.

30. Carsten Gräbel, *Die Erforschung der Kolonien: Expeditionen und koloniale Wissenskultur deutscher Geographen, 1884–1919* (Bielefeld: Transcript Verlag, 2015), on 82, 102; Jürgen Zimmerer, "Im Dienste des Imperiums. Die Geographen der Berliner Universität zwischen Kolonialwissenschaften und Ostforschung," *Jahrbuch für Universitätsgeschichte* 7 (2004): 73–100.

(*Lebens- und Betätigungsraum*).[31] When in Tanganyika, Troll had visited German planters and farmers. The German colonists had been allowed back in Africa soon after Germany had joined the League of Nations, in 1925. Although Troll expressed respect for British colonial administration, he argued that the colonists in Tanganyika would be far better off under German rule.[32]

At the end of 1937, Troll moved to Bonn, where he was offered the Chair (Ordinarius) in Geography. During his Bonn tenure, Troll's interest in colonial matters did not diminish in the least, and he pointed to "possibilities," as in an article, published in 1941, the title of which translates as "Scientific aerial photography research as preparation for the opening up of the colonies."[33]

The Nazi party, so it seems, turned a deaf ear to Troll's pleas for regaining the African colonies. When it came to power in 1933, it did not prioritize colonial policy, even when it established a *Kolonialpolitische Amt* (Colonial Policy Office) in 1934. Over the years, the Nazis warmed to the idea of getting the colonies back, but they left it at propaganda. The realities of the war led them in 1943 to finally relinquish the colonial dream. In fact, Nazi priority had always been with German expansion to eastern Europe, or *Ostsiedlung*. After the War, Troll would point at this to exculpate himself of any suspicions pertaining to having served the Nazis.

Troll on Fundamental and Applied Research

In 1947, Troll published a lengthy account of the fate of German geography during 1933–1945, and also came out in English, although in a somewhat abbreviated form.[34] Among the many bad things he describes, there were a few good things, and these concerned, mainly, the Gesellschaft für Erdkunde zu Berlin (Society for Earth Science at Berlin), of which Troll had been Chair.

31. Carl Troll's notes of 8 Jul 1934 (Archiv Geogr. Inst. Uni. Bonn, IV-72), quoted in Hans Böhm, "Carl Troll—Wissenschaftler in der NS-Zeit," address at Festkolloquium im Rückblick auf den 100 Geburtstag von Carl Troll (Festive Seminar in Remembrance of Carl Troll's 100th birthday), Bonn, 11 Dec 2000, www.geographiegeschichte.de (accessed 20 Sep 2011).

32. Carl Troll, *Das deutsche Kolonialproblem auf Grund einer Ostafrikanischen Forschungsreise 1933/1934* (Berlin: Dietrich Reimer, 1935), on 25, 54–55.

33. Carl Troll, "Wissenschafliche Luftbildforschung als Wegbereiterin kolonialer Erschliessung," *Beiträge zur Kolonialforschung* 1 (1941): 9–19.

34. Carl Troll, "Die geographische Wissenschaft in Deutschland in den Jahren 1933 bis 1945," *Erdkunde* 1 (1947): 3–48; Carl Troll, "Geographic Science in Germany during the Period 1933–1945: A critique and justification," *Annals of the Association of American Geographers* 39 (1949): 99–137.

Troll maintained that he had been "completely successful throughout the entire period in preserving [the Society's] strictly scientific character in lectures and in its journal. . . ." The basic science policy of the Society extended to aerial photography research, overseen by a Committee chaired by himself.

Troll related that while in Berlin, he had pursued colonial research in the abstract because, as he pointed out, the Nazi Party maintained the policy line that colonies were against German interest.[35] Upon his return from Nanga Parbat, the Nazis had changed their viewpoint, and Troll was put under pressure to apply for Party membership. The Bonn offer, so Troll claimed, was made at just the right time for him to be able to sidestep this dilemma. As Ordinarius, Troll could portray himself as a practitioner of pure, basic science.[36] Indeed, he never held a membership card for the Nazi Party.[37]

Through this account, Troll framed the public view of his own role and the Society's for decades. He tapped into a distinction between fundamental and applied research, which had been reestablished in Germany after the War, in part under the influence of the allied forces, and which had become enormously influential after World War II in most Western countries. Before and during the War, applied (*völkisch*: "people"-oriented) research in geography had been seen as serving the interests of the regime.[38] By anachronistically insisting on a distinction that was not in place back then, Troll was able to hide his contributions to the German war effort. It did not come to light until more than a decade after his death in 1975, and when it did, it met with disbelief.[39]

The late German geographer Hans Böhm was a former student of Troll's and his successor at the Bonn Chair. Böhm published a number of Troll's letters and private notebooks during the period spanning 1933–1947, stemming from his archival research at Bonn University into the history of its geography department.[40] The documents make it clear that Troll was indeed engaged

35. Troll, "geographische Wissenschaft" (ref. 34).

36. Carl Troll, quoted in Hans Böhm, "Forschungen unter Leitung von C. Troll, 1938–1948," in *Beiträge zur Geschichte der Geographie an der Universität Bonn*, ed. Böhm (Bonn: Ferd. Dümmlers Verlag, 1991), 108–17, 241–49, on 245.

37. Instead, Troll was "Nicht-Partei-Mitglied der NSDAP," a sort of aspirant status; Sabine Richter, archivist University of Bonn, Deutschlandfunk 24 Jan 2003, www.deutschlandfunk.de.

38. Nicolas Ginsburger, "La géographie universitaire allemande revisitée," *L'espace géographique* 40 (2011): 193–214, on 196.

39. K. W. Butzer, "Practicing Geography in a Totalitarian State: (Re)Casting Carl Troll as a Nazi Collaborator?," *Erde* 135 (2004): 223–31.

40. Böhm, "Forschungen" (ref. 36); Hans Böhm, "Luftbildforschung" (ref. 29); Böhm, "Carl Troll—Wissenschaftler" (ref. 31).

with what he saw as basic research in geography, but as we have already seen, over and beyond that with its applications, too. Troll's letters tell us that, when the regime finally adopted a more pro-colonial policy, it did not make him a good enough offer.[41] Troll's choice for Bonn was therefore opportunistic.

Despite Troll's later assertion to the contrary, Troll had offered his services with regard to to forestry and forest management in Europe, from 1939, on especially with regard to the "new space in the German east" (*Deutsche Reich im neuen Ostraum*, the annexed parts of Poland, Czechoslovakia, and Ukraine).[42] As early as 1935, right after his first Africa trip, Troll had argued that colonial settlement and eastward expansion in Europe served two different but complementary goals: raw materials and other revenues in the former and mass settlement in the latter. The colonies could not provide opportunities for mass settlement. Tanganyika in particular would not be able to accomodate very many German planters and farmers, who moreover should make the African population work for them, in a "racial layering" (*rassische Schichtung*), further setting a limit to German presence in terms of numbers.[43] Next to social and economic considerations of this sort, Troll advocated prudent colonial settlement on ecological grounds. In traditional African land use, the pattern of the natural landscape was respected, according to Troll. In modern times, we too often ignore the fine structure of the landscape, and we do this at our peril.[44] This insight, Troll insisted in 1935, "would show as unfounded the objection that the colonial question served

41. Carl Troll, letter to H. Cloos, 10 Nov 1937, printed in Böhm, "Forschungen" (ref. 36), 243. Troll had apparently intimated to some individuals that he disapproved of the heroism surrounding the climbing of the Nanga Parbat. The Nazi regime may have held that against Troll.

42. Troll, in Böhm, "Forschungen" (ref. 36), 115, 242. See also Carl Troll, "Bodenkunde, Vegetationsforschung und Geomorphologie als Grundlage der Wirtschaftsplanung in Neuländern," *Geographische Zeitschrift* 50 (1944): 128–32. In 1938, Troll visited Romania by order of Germany's Foreign Office, advising on the production of a "historisch-geographische Atlas von Europa"; see Hans Böhm, "Magie eines Konstruktes. Anmerkungen zu M. Fahlbusch 'Wissenschaft im Dienst der nationalsozialistischen Politik?'," *Geographische Zeitschrift* 88 (2000): 177–96. On the German economic and agronomic planning of the new German east, see also Götz Aly and Susanne Heim, *Vordenker der Vernichtung: Auschwitz und die deutschen Pläne für eine neue europäische Ordnung* (Hamburg: Hoffmann und Campe, 1991) and Ginsburger, "Géographie allemande" (ref. 38).

43. Troll, *Kolonialgeographische Forschung* (ref. 28), 9, 13; Troll, *Das deutsche Kolonialproblem* (ref. 32) on 55, 57.

44. Troll, *Das deutsche Kolonialproblem* (ref. 32), 57; Troll, "Wissenschafliche" (ref. 33). For similar arguments made by French anthropologists and geographers in the 1930s, also in the context of colonial research, see Haffner, *View from above* (ref. 1), 19–54.

to divert attention away from the great plans regarding . . . *Ostsiedlung*, involving [settlement] on a massive scale."[45]

Troll argued that European expansion could benefit from aerial photography just as colonial policy could. He worked with Hansa Luftbild GmbH to develop aerial photography in the context of Germany's war in Europe. In 1941, the German Air Transport Department (*Luftfahrtministerium*) raised the status of aerial photography from "applied research" to "war relevant" (*kriegswichtig*). The next year, the Department organized a workshop (*Arbeitstagung*) on the subject, with Troll giving the introductory address.[46] The most substantial result of this workshop for Troll was that he received funding to have Russian scientific publications on aerial research translated into German.[47] A further rise in status occurred in 1944, when *Luftbildforschung* (research through aerial photography) became *militärisch notwendig* (militarily necessary).[48] But again, the regime failed to acknowledge the role Troll had claimed for himself. Troll complained that the Air Transport Department failed to make full use of the Gesellschaft für Erdkunde.[49] As late as on February 19, 1945, Troll wrote to a colleague: "Usually, science is seen as an occasional piece of assistance for a technical question. One does not see the war potential of the scientific *Geist* and the leading scholars."[50]

As we have seen, after the war Troll was extraordinarily successful in hiding from colleagues at home and abroad the offers for service he had made to the Nazi regime. If, however, the regime had accepted more enthusiastically the offers Troll made, at first in the context of colonial policy, later in the context of the annexation of Poland, his post-war career could not have been quite so successful.[51]

45. Troll, *Das deutsche Kolonialproblem* (ref. 32), 60.

46. Böhm, "Luftbildforschung" (ref. 29), 136.

47. Troll gave an overview of Soviet-Russian aerial photography in his "Fortschritte der wissenschaftliche Luftbildforschung," *Ztschr. Ges. Erdk. Berlin* (1943): 121–46.

48. Böhm, "Luftbildforschung" (ref. 29), 136–37.

49. Sören Flachowsky, "'Die Forschungsgruppe Schulz-Kampfhenkel steht jetzt für Ostausgaben zur Verfügung': Otto Schulz-Kampfhenkel als Beauftragter für Sonderaufgaben der erdkundlichen Forschung," in *Von Amazonas an die Ostfront: der Expeditionsreisende Otto Schulz-Kampfhenkel (1910–1989)*, ed. S. Flachowsky and H. Stoecker (Cologne: Böhlau Verlag, 2011), 240–302, on 269.

50. "Man will immer noch die Wissenschaft nur für Handlangerdienste für technische Einzelfrage gelten lassen, sieht aber nicht ein, welches Kriegspotential im wissenschaftlichen Geist und im zentralen Einsatz führender Gelehrter schlummert," quoted in Böhm, "Luftbildforschung" (ref. 29), 137.

51. Other German geographers apparently had drawn the attention of the Nazi authorities more successfully than Troll. A case in point is Otto Schulz-Kampfhenkel. Another tentative

We may dryly observe that aerial photography had originated in a field of practical application: the military, during World War I. Colonial research came second, together with applications such as for archeological research. In the 1930s, in France, aerial photography was put to use in urban and spatial planning.[52] In 1944–1945, aerial photography was put once again in the service of the military and not only by Germany; the U.S. Eighth Air Force and the British Royal Air Force continuously monitored the effects of air strikes on German cities.[53] After World War II, the distinction between fundamental and applied research was not upheld everywhere to the same extent. Zonneveld would make no bones about the societal relevance of a geography based on aerial surveys. On the contrary, he knew his studies would serve land use and land development projects.[54] Troll had in a sense appreciated correctly the value of aerial photography for geographical research of vast stretches of uncharted land in Africa and Asia, and he had been willing to go to great lengths to pursue them.

PLANT SOCIOLOGISTS AND THE VIEW ON THE GROUND

Troll always navigated the field of plant sociology with uneasy tension. During World War II, Troll gave a telling characterization of his view: "The current crisis of plant sociology, and this is now increasingly recognized, is that it takes the floristic unit as a given and not the biotope."[55] Troll surely meant to include the soil characteristics in his definition of "biotope." Twenty years later, Troll treated phytosociology particularly harshly in a book review. He noted that the methods of phytosociology produced visual understanding (*Anschaulichkeit*) and ecological understanding of the vegetational cover of the land via difficult detours only. He went on to state that it was phytosociology

explanation for Troll's relative sidelining is that the authorities had been piqued by Troll's lack of enthusiasm about the heroism surrounding the Nanga Parbat expedition. See Böhm, "Carl Troll—Wissenschaftler" (ref. 31), 14.

52. Haffner, *View from Above* (ref. 1), 19–54.

53. Götz Bergander, *Dresden im Luftkrieg: Vorgeschichte, Zerstörung, Folgen* (Cologne: Flechsig/Böhlau, 1998).

54. I. S. Zonneveld, "The Land Unit: A Fundamental Unit in Landscape Ecology, and its Implications," *Landscape Ecology* 3, no. 2 (1989): 67–86.

55. "Die ganze gegenwärtige Krise der Pflanzensoziologie geht, wie heute mehr und mehr erkannt wird, darauf zurück, dass sie den floristischen Bestand als gegebene Grösse und nicht die Standorteinheit, das Biotop, zum Ausgang nimmt"; Troll, "Bodenkunde" (ref. 42), 131.

that had made Germany lag behind other nations in the field of vegetational mapping. Troll blamed phytosociology's dominance of the *Zentralstelle für Vegetationskartierung* for this unhappy situation.[56]

The *Zentralstelle* had been founded in 1939 by Reinhold Tüxen, Germany's most important practitioner of the Zürich-Montpellier school of plant sociology. Tüxen had stayed on as Director of the Zentralstelle for over 25 years, that is, until the time Troll wrote the review. The acknowledged leader of the phytosociological school (also called the French-Swiss school) was Swiss-born Josias Braun-Blanquet.[57] Braun-Blanquet had been a doctoral student of Charles Flahault, who in his plant geographical work had also combined floristics with statistics.[58]

Phytosociology, because of its close proximity in a disciplinary respect with phytogeography, was seen by Troll as a competitor, if not directly for funds, then for status and policy influence. Troll was President of the Phytogeography Section of the International Union of Biological Sciences and presided in that capacity over many conference sessions attended by Braun-Blanquet and Tüxen (Fig. 2).[59] It is noteworthy that in a review simultaneously published with the review previously mentioned, Troll speaks about Braun-Blanquet's "masterly work."[60] What are we to make of this?

Theoretical Assumptions of Braun-Blanquet

The core theoretical assumption of Braun-Blanquet and (more or less implicitly) of his entire school is captured in a metaphor: the round table

56. Troll praised Ellenberg's book, even while noting that it had been guided by phytosociological principles. But he noted with satisfaction that Ellenberg had often taken recourse to a "physiognomic" approach. See Carl Troll, "Das Pflanzenkleid Mitteleuropas. Zur Heinz Ellenbergs 'Vegetation Mitteleuropas mit den Alpen'," *Erdkunde* 20 (1966): 303–05.

57. Also named the Zürich-Montpellier school and Sigmatists (named after SIGMA, the acronym of the institution founded by Braun-Blanquet and his wife in Montpellier). SIGMA was privately funded and operated alongside and in cooperation with the University of Montpellier.

58. Flahault's academic lineage can be traced back directly to Augustin-Pyramus de Candolle and his "biological arithmetic." On Candolle, see Jane Browne, *The Secular Ark: Studies in the History of Biogeography* (New Haven, CT: Yale University Press, 1983); Maurice Crosland, *The Society of Arceuil: A view of French science at the time of Napoleon I* (London: Heinemann, 1967). On Flahault, see Patrick Matagne, *Aux origines de l'écologie: Les naturalistes en France de 1800 à 1914* (Paris: Éditions du CHTS, 1999).

59. J. J. Barkman, "On the Sessions of the Section Phytogeography. VIIth International Botanical Congress, Stockholm, 1950," *Vegetatio* 3 (1951): 146–48.

60. Carl Troll, "Die geobotanische Landesaufnahme der Schweiz (zu ihrem 50-Jahres Jubiläum) und das geobotanischen Institut, Stiftung Rübel," *Erdkunde* 20 (1966): 305–07.

FIGURE 2. Picture taken at the final session of the Section Phytogeography, Stockholm, 1950. Front row, second from left, J. Braun-Blanquet; third from left, R. Tüxen; fifth from left, C. Troll. Source: J. J. Barkman, "On the Sessions of the Section Phytogeography. VIIth International Botanical Congress, Stockholm, 1950," *Vegetatio* 3 (1951): 146–48.

(*Tafelrunde*), a place, stand, or habitat (*Standort*) at which the members of a society of plants (*Gesellschaftsglieder*) "sit" together as table companions. Braun-Blanquet borrowed the term from the Belgian zoologist and parasitologist Pierre-Joseph van Beneden. The latter had derived the metaphor from the older concept of commensalism, thereby uniting cooperative and competitive relationships in a more generalized fashion. The Danish ecologist Eugenius Warming had mentioned the "table companions" metaphor approvingly.[61] It was Braun-Blanquet, however, who employed the metaphor in a rather precise manner, and he developed an elaborated vocabulary on its basis. According to Braun-Blanquet, some members of a plant society have a strong preference for a particular kind of place where they find a special kind of food (*Feinschmecker,* gourmets), whereas others care less where they sit down.[62] The concept of the "fidelity" (*Gesellschaftstreue*) of a plant to its preferred plant associations is also derived from the "table companions" metaphor. Whereas one plant may join a variety of plant societies, others (notably the valued rare species) are more finicky in their choice of table companions and may confine themselves to one

61. Eugenius Warming, *Oecology of Plants: An introduction to the study of plant-communities* (Oxford: Clarendon Press, 1909), on 92.

62. Braun-Blanquet, *Pflanzensoziologie*, 2nd ed. (ref. 10), 14–16.

preferred set.[63] This marks them as more or less reliable indicators of a specific association, hence their designation as "characteristic species." In some cases, plants make foods accessible to others that they, themselves, do not need, whereas in other cases, individual plants feast on the varying courses offered in a common environment. In yet other cases, plants help each other to keep potentially dangerous competitors away. At any rate, plant associations have a distinct and stable composition, *gesetzmässig*, according to natural laws.[64]

Competition may occur *between* plant communities. In some such cases, "the aggressive domineering species of great dynamic and genetic significance play the role of advance guard and main army; the more or less constant companions furnish the reserves."[65] It can be readily derived from these assumptions that there is not a one-to-one relationship between a particular set of climatic and soil conditions and its vegetational cover, such as Troll would have liked to see it. A particular community may be in a certain habitat because a certain plant arrived there first, allowing some plants to join but not others. Important as environmental factors are, it is sociological relationships between plants that have primacy.

There is no standard or typical size of the area occupied by a single community or association. Generally speaking, vegetational analysis in the phytosociological manner is fine-grained, and plant associations may have the size of just one square meter, but areas much larger than that are not uncommon. Braun-Blanquet's taxonomy does not stop here.[66] Several associations together build a formation (*Verband*, alliance), which is a more highly ranked individual than an association; formations, in their turn, go on to form still larger and more highly ranked individual groups: plant orders, vegetation classes, and the *Gesellschaftskreis*, the latter occupying good portions of a continent.

Despite the fact that Braun-Blanquet had followers in the thousands, his students rarely mentioned the "table companions" metaphor. Tüxen's student Heinz Ellenberg was one of few to point out that plants in an association are

63. Ibid., 95.

64. Ibid., 18. There is a degree to which phytosociologists allow for small differences between exemplars of the same association. They remind us that the identification of a particular plant association is the result of a taxonomic effort, hence their designation of associations as "abstract." Although the word "abstract" has given rise to some confusion, it is in fact similar to the use of the word "tiger" for a species.

65. Braun-Blanquet, *Pflanzensoziologie*, 1st ed. (ref. 10), 16; Braun-Blanquet, *Pflanzensoziologie*, 2nd ed. (ref. 10), 439.

66. Braun-Blanquet, *Pflanzensoziologie*, 2nd ed. (ref. 10), 562–76.

"partners," thus retaining a part of the analogy.[67] Victor Westhoff and Eddy van der Maarel, two Dutch phytosociologists, correctly observed in an often cited overview that phytosociology occupies a middle position between individualistic and holistic approaches in plant ecology, but they apparently avoid mentioning the metaphor itself.[68] However, concepts informed by the metaphor of table companions, but which receive a more circumscribed technical usage, are used by every phytosociologist. Usually, the "principle of fidelity" is referred to as the cornerstone of the phytosociological tradition.

Braun-Blanquet's theory marks the association as, in fact, a theoretical entity. In principle, that makes the association not any less a scientific concept, but it explains the possibility of skepticism.[69] Many British and American ecologists, certainly those working from an individualistic or Gleasonian perspective, doubted the very existence of the plant association.[70]

Methodological Principles of the Braun-Blanquet School

The methodology of the French-Swiss school is contained in the *relevé*, the list of plants, drawn up at a number of quadrats, very often in square meters, although the size of the plots is variable according to circumstances.[71] Two main aspects of each plant are recorded on the spot: estimated frequency or abundance and "sociability," the latter an expression of the spatial pattern in which the plant occurs: solitary or in patches. On the basis of a number of *relevés*, vegetational units such as plant associations (and higher-order units such as plant formations) are identified, and maps may be produced, but only after computations of the data obtained from the *relevés* have been made. The

67. Heinz Ellenberg, "Zur Entwicklung der Vegetationssystematik in Mitteleuropa," in *Festschrift für Erwin Aichinger zur 60. Geburtstag, Band I* (Vienna: Springer, 1954), 134–43, on 135.

68. V. Westhoff and E. Van der Maarel, "The Braun-Blanquet Approach," in *Ordination and Classification of Communities*, ed. Robert H. Whittaker (The Hague: Junk, 1973), 617–701.

69. Henry Gleason was the author of the so-called individualistic hypothesis. See Malcolm Nicolson and Robert P. McIntosh, "H. A. Gleason and the Individualistic Hypothesis Revisited," *Bulletin of the Ecological Society of America* 83 (2002): 133–42.

70. Robert Whittaker and David Goodall, along with Robert P. McIntosh and others, in the 1950s developed a very different take on vegetational patterns, seeing them as emerging from the intersection of a large number of more or less independent environmental variables, as opposed to the discrete vegetational entities of the Europeans. See David Goodall, "A Century of Vegetation Science," *Journal of Vegetation Science* 25 (2014): 913–16, written at the occasion of Goodall's 100th birthday.

71. Schulte Fischedick, "Practices and Pluralism" (ref. 2); Westhoff and Van der Maarel, "The Braun-Blanquet Approach" (ref. 68), 637.

classical procedure is to assemble the various *relevés* in tables. The tables are manipulated and rearranged in up to six steps, from the "raw table" to the "ordered table." Through the rearranging, a pattern emerges, leading to the identification of several distinct plant communities. The procedure became more or less standardized in the 1930s, at the Zentralstelle für Vegetationskartierung (renamed Bundesanstalt für Vegetationskartierung after WW II) under the guidance of Tüxen, on the basis of directions from Braun-Blanquet.[72] The method found a first expression in a 1937 publication by Tüxen.[73] Braun-Blanquet himself, in the first edition of his textbook, had given only the briefest indication of the "association table" methodology, not presenting an arithmetic.[74] Plant associations and plant formations are identified on a purely floristic basis, without taking soil or climate features into account. Only afterward is a relationship sought with abiotic factors. Prior to the large-scale introduction of the computer in scientific practice, the procedure was difficult to learn and burdensome to handle. Tüxen himself had an experienced staff ("the girls of the Bundesanstalt") carrying out the table manipulations for him.[75]

Although the computational procedure of phytosociology differs sharply from Troll's methodology (who, as we have seen, completed previously delineated areas), how the locations of the phytosociological *relevés* are selected is another matter. The perhaps surprising answer is: visually. Braun-Blanquet demanded floristic homogeneity for any plot of land selected for a *relevé*.[76] This homogeneity was to be ascertained "physiognomically," that is, by the

72. Westhoff and Van der Maarel, "Braun-Blanquet Approach" (ref. 68), 650.

73. Reinhold Tüxen, *Die Pflanzengesellschaften Nordwestdeutschlands. Mitteilungen der Floristisch-soziologischen ArbeitsGemeinschaft in Niedersachsen Heft 3* (Hannover: Engelhard, 1937).

74. Braun-Blanquet, *Pflanzensoziologie*, 1st ed. (ref. 10), 67. Braun-Blanquet, in the second edition of *Pflanzensoziologie* (ref. 10), 81, again does not present a table arithmetic, but instead refers to the "analyse statistique des tableaux de végétation" by H. Etter, "De l'analyse statistique des tableaux de végétation," *Vegetatio* 1 (1949): 147–54. The table arithmetic, however, is not complete in the article by Etter. A full description of the transition from the first raw table to the final table is given in Alexis Scamoni, *Einführung in die praktischen Vegetationskunde* (Berlin: Deutsche Verlag der Wissenschaften, 1955), 45–52.

75. In 1970, Tüxen insisted, when confronted with the advantages of the computer, "Ich finde doch die Mädchen der Bundesanstalt für Vegetationskartierung billiger—und auch schöner" (I find the girls of the Bundesanstalt cheaper, and prettier, too), quoted by J. Moore, "Discussion," in *Grundfragen und Methoden in der Pflanzensoziologie (Basic Problems and Methods in Phytosociology): Bericht über das internationale Symposion der internationalen Vereinigung für Vegetationskunde in Rinteln*, ed. R. Tüxen, (Den Haag: W. Junk, 1972), 258–59.

76. Braun-Blanquet, *Pflanzensoziologie*, 2nd ed. (ref. 10), 53.

looks of the area. The physiognomic criteria of Braun-Blanquet seem to build a communality with Troll's visual approach, and this becomes all the more apparent when noticing that Braun-Blanquet spoke highly of aerial photography (*Luftkartierung*). He wrote: "under good light conditions, individual plant societies, associations and formations can be identified from a height of 2000 meters, *on the condition that one is familiar with the plant societies*."[77] This textbook passage may well have been the basis for Troll's appreciation of Braun-Blanquet. Yet two comments are in order. One is that Troll worked on the basis of more obviously available visual units that served him as gestalts, whereas the visual units of Braun-Blanquet required specialist's knowledge. Another is that Braun-Blanquet's enthusiasm for aerial photography was not adopted by his followers, and apparently, Braun-Blanquet himself did not pursue its use actively or practice it much himself. We may note that phytosociologists of lesser stature than Braun-Blanquet would simply not dare to identify associations in a direct visual manner, not even Tüxen. Instead, they would painstakingly rely on the correct application of the phytosociological methodology, as we will see in more detail below.

The plant sociological gaze was a contentious issue, right at the introduction of this aspect of Braun-Blanquet's methodology, and long after. During the 1920s, Dutch adherents of the so-called Nordic school in phytosociology rejected it, and advocated instead a completely random selection of sampling plots. Neither were they satisfied with visual estimation of frequency and sociability, demanding instead strict counting, weighing, and measuring. Criticizing Braun-Blanquet's physiognomic gaze, they implied his methodology was circular: plant societies were inferred from *relevés*, whereas the plots of the *relevés* were selected on the basis of advance knowledge of the societies. In a typical statisticians' stance, they called Braun-Blanquet "subjective" and claimed objectivity for themselves.[78]

In contrast, the word "statistics" occurs only once, and then only in a reference, in Braun-Blanquet's work, even though his procedure to infer plant societies from the *relevés* was a data-sorting arithmetic. Tüxen's refinement of the methodology was apparently developed without the support of mathematical statisticians. Braun-Blanquet and Tüxen relied on an intuitive arithmetic,

77. Ibid., 551 (emphasis added): "Bei günstiger Beleuchtung lassen sich noch aus Höhen von 2000 m einzelne Pflanzengesellschaften, Assoziationen und Verbände unterscheiden und auch aus dem Flugzeug direkt kartographisch aufnehmen, vorausgesetzt, dass die Gesellschaften bekannt sind."

78. Schulte Fischedick, "Practices and Pluralism" (ref. 2), 137–61.

along with the visual recognition of "types."[79] It served them well, and many others in the field, too.

Phytosociologists of the Braun-Blanquet school were not shy in admitting that the selecting of the plots of the *relevés* was subjective. Yet they argued that it was not possible to act otherwise. Ellenberg remarked:

> The collection of plants regularly seen in all *relevés* in particular, but also the collection of characteristic species, is dependent on the choice of the *relevé* areas as well as on the *relevés* included in the tables. In both cases, subjective judgment, experience, and the "art" of the researcher plays an essential role.[80]

After World War II, the continental European phytosociologists were increasingly urged to adopt statistical methods, most vocally by the American ecologists Robert Whittaker and David Goodall. Tüxen and several more German, French, and Dutch phytosociologists were willing to do so. In 1970, an encounter took place in Germany, at the occasion of the fourteenth symposium of the *Internationale Vereinigung für Vegetationskunde* (since 1981, named the International Association for Vegetation Science). According to Tüxen, the aim of the conference was "to forge a synthesis between mathematics and vegetation science," and between "the Anglo-American and the European *Auffassung*."[81]

79. Tüxen: "Das Klare und Präzise an einem solchen Typus ist immer sein Kern, nicht seinem Rand . . . Echte Typen sind keine Sammelschachteln sondern Brennpunkte" (What is clear and precise in such a type is always in its centre, not on its margin. Real types are not collections but foci); see Reinhold Tüxen, "Das System der nordwestdeutschen Pflanzengesellschaften," *Mitteilungen der Floristisch-Soziologischen Arbeitsgemeinschaft, Neue Folge* 5 (1955): 155–76. The word "types" was, as far as I have been able to ascertain, used almost exclusively by Tüxen, but no fellow phytosociologists ever objected to the use of the term. Ellenberg mentioned it, using the occasion to point out that types may differ between different researchers; see Ellenberg, "Zur Entwicklung" (ref. 67). Tüxen's use of the term was mentioned with apparent approval by Westhoff and Van der Maarel, "Braun-Blanquet Approach" (ref. 68), 630. Tüxen's "type" is consistent with Max Weber's ideal types. Therefore, associations as categories are abstractions made on the basis of repeated observations, enabling the researcher to build an intimate knowledge of the land and to leave out nonessential aspects in his categorizations. A bit of essentialism in the conceptualization of types cannot be totally excluded, though.

80. "Besonders die Gruppe der regelmäßig in allen Beständen auftretenden Arten, aber auch die Gruppe der Charakterarten ist somit abhängig von der Wahl der Aufnahmeflächen sowie der Auswahl der Aufnahmen, die man in der Tabelle beläßt. Beide Male spielt also das subjektive Ermessen, die Erfahrung und die 'Kunst' des Bearbeiters eine wesentliche Rolle"; Ellenberg, "Zur Entwicklung" (ref. 67), 137.

81. Reinhold Tüxen, ed., *Grundfragen und Methoden in der Pflanzensoziologie* [Basic Problems and Methods in Phytosociology]*: Bericht über das internationale Symposion der internationalen Vereinigung für Vegetationskunde in Rinteln* (Den Haag: W. Junk, 1972), on 55.

Whittaker was present. Several conference participants identified themselves as propounding the statistical approach to vegetation science, advocating factor analysis and Principal Component Analysis, and at any rate insisting not to rely on "subjective" methods at all. Several were adamant about that.[82]

Yet Tüxen and others often pitted themselves against "the mathematicians." Tüxen insisted that investigations of vegetations with statistical methods were not particularly valuable to him when the areas under investigation had not been ascertained beforehand as "typical." Several other participants agreed.[83] So despite Tüxen's good intentions, positions on the phytosociological gaze remained divided, as testified by a large review article written a few years later by two Dutch top-ranking adherents of the Zürich-Montpellier school. Westhoff and Van der Maarel wrote: "a subjective, 'stratified' sample selection is far superior to sample choice by random points on a map."[84] They went on to describe what they meant by that: "The first condition is that no obvious structural boundaries or variation in stratification are visible within the stand."[85]

This is the easy part. In many cases there are sharp distinctions between associations, similar to the kind of changes on which Troll relied. But they continued as follows:

> The second criterion is uniform floristic composition. It is usual to look for joint patterns of dominant and/or abundant species and then to delimit a stand where qualitative changes in patterns occur, i.e., where one or more species drop out and others come in. In many cases an experienced field worker is able to judge this rapidly.[86]

Here the authors do not refer to abrupt changes in the dominant species themselves, and they are making room for the more subtle visual changes marked by the presence of less dominant species, those with potential "high fidelity" to a particular plant formation. It was received knowledge among the plant sociologists that dominant species were *not* in fact reliable markers of plant associations, since it is "an experiential fact that one and the same kind of

82. See the exchanges between L. Fresco and H. Doing, ibid., on 73–74, and again between Fresco and others on 162–67 and 173–82.

83. Tüxen, "Discussion" (ref. 81), 163–64; J. J. Barkman, "Discussion," in Tüxen, *Grundfragen und Methoden* (ref. 81), 177–78.

84. Westhoff and Van der Maarel, "Braun-Blanquet Approach" (ref. 68), 631–32.

85. Ibid., 632.

86. Ibid., 632.

plant species can become a dominant species at various different habitats. Therefore, typical dominant plants are not reliable habitat indicators."[87]

Being able to see the more subtle, yet "qualitatitive" changes in the vegetation obviously requires specialized floristic knowledge on the side of the field worker, who in addition should have the sensibility to know when and where to look for them, as a less experienced field worker might miss them altogether. It is a visual skill based on "trained judgment" and to some extent comparable to the gestalt perception of species identity British naturalists call *jizz*.[88]

We find a similar admonition to the visual ascertaining of homogeneity in a contemporary handbook by two German top-ranking vegetation scientists. Discussing the minimal size of a plot for a *relevé*, they wrote

> The minimal area can only be determined in a community that is relatively homogeneous and not fragmentary. A community can be called fragmentary if it lacks species that are usually present in the recurrent plant assemblages of this kind.[89]

Again, distinguishing beween the fragmentary and the homeogeneous is said to require specialized knowledge, not only of floristics but of the Braun-Blanquet plant associations as well.

Yet, the phytosociologists were walking a thin line, and they were well aware of it. As we have seen, they demanded that the area be "typical." But it was not permitted to ascertain beforehand the rare species that were considered to be "character species" and so to have established the association before even starting with the *relevé*. Tüxen warned against the temptation to do so, and he insisted that "character species" should be identified through the tables, hence inductively from the data.[90] Yet the fact that he felt compelled to issue the warning is telling.

The precedence of the visual over the randomly selected plot is illustrated dramatically in Figure 3. The diagram appears in a much used textbook of phytosociology by Hartmut Dierschke, a student of Tüxen and Ellenberg.[91]

87. "... die Erfahrungstatsache, daß ein und dieselbe Pflanzenart auf verschiedenen Standorten zur Herrschaft gelangen kann, daß also Dominanztypen kein zuverlässigen Standortsweiser sind," Ellenberg, "zur Entwicklung" (ref. 67), 136.

88. Rebecca Ellis, "*Jizz* and the Joy of Pattern Recognition: Virtuosity, discipline and the agency of insight in UK naturalists' art of seeing," *Social Studies of Science* 41 (2011): 769–90.

89. Dieter Mueller-Dombois and Heinz Ellenberg, *Aims and Methods of Vegetation Ecology* (New York: John Wiley, 1974), on 48.

90. Tüxen, "Discussion" (ref. 81), 235.

91. Dierschke, *Pflanzensoziologie* (ref. 2), 150.

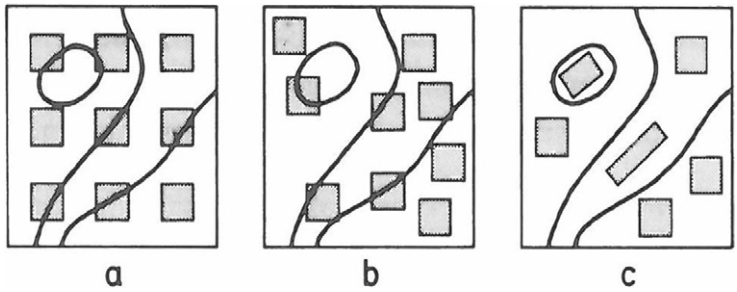

FIGURE 3. Source: Helmut Dierschke, *Pflanzensoziologie* (Stuttgart: Eugen Ulmer), 150.

On its basis Dierschke argues that although the first two ways of selecting plots look more objective, they make no sense. According to the caption that goes with the figure, in (a) (systematic plotting) and (b) (randomized plotting), the smallest vegetational type is missed while much effort is wasted on non-homogeneous plots.

But just how "qualitatively different" these visual units are was a contentious matter, and it would remain so among the phytosociologists themselves. We have seen, above, Van der Maarel and Westhoff's justification of "subjective stratified sampling." Stratified sampling is a concept borrowed from statistics, meaning that if one takes samples from a population and one knows beforehand that the population consists of relatively independent subpopulations, one should take care that the various subpopulations are represented among the samples. The subpopulations are called "strata."[92] The subpopulations need to be well defined, and many ecologists, including some phytosociologists, denied that this is in fact the case. Hence the charge, voiced in *Vegetatio*, that ecologists had "generally applied uncritically the well-established principles and procedures of classical sampling theory."[93]

On the second major aspect of the Braun-Blanquet method, the numerical analysis of the *relevés*, the 1970 conference did mark a rapprochement with the "objectivist" approaches represented at the conference. In particular, Eddy van der Maarel's comparative analysis of 51 plant communities, a search for phytosociological units above the level of plant communities, was greeted with interest and approval by Robert Whittaker. Van der Maarel presented a "principle components analysis" with the help of a Fortran IV program written for

92. William G. Cochrin, *Sampling Techniques* (New York: John Wiley & Sons, 1953).

93. N. C. Kenkel, P. Juhász-Nagy, and J. Podani, "On Sampling Procedures in Population and Community Ecology," *Vegetatio* 83 (1989): 195–207.

him by a colleague at the Department of Mathematical Psychology, and carried out on an IBM 360–50 computer at the University of Nijmegen.[94] At around the same time, Van der Maarel was also among the pioneers of new methods of data storage and data computation, enabling the reuse of previously acquired *relevés*.[95] *Relevé* data were stored on punch cards instead of merely being kept in field notebooks. Yet, ultimately, the merge between classical phytosociology and more rigorous statistical methods as championed by U.S. ecologists was resisted by Tüxen. In 1973, he withdrew from the editorial board of *Vegetatio*, a journal founded by Braun-Blanquet (in 1948) and of which Van der Maarel was Editor-in-chief. Tüxen went on to found a new journal, *Phytocoenologia*.[96] The new journal continued to publish studies based on "manual table work and geographical comparisons" and "regional descriptions of hitherto little known areas," as Van der Maarel put it, whereas *Vegetatio* was at risk of becoming a mathematical journal in the eyes of many readers.[97] After 1973, the German contribution to *Vegetatio* fell from 20 percent to below 5 percent, whereas the Dutch contribution rose to 20 percent, along with a marked U.S. presence of 16 percent. Both journals still exist (*Vegetatio* was renamed *Plant Ecology*), but in 1989, yet another journal was launched by Van der Maarel, the *Journal of Vegetation Science*, with the stated aim of reuniting the phytosociologists. Apparently it has been successful in doing so.[98]

Yet, even when we take into consideration the reliance on visual appreciation of the vegetational cover of the landscape in the original Braun-Blanquet approach, it should be pointed out that at no point did the phytosociologists make use of visual materials on which to carry out analyses of plant associations and the higher units of plant groups. Braun-Blanquet's textbook, in its various editions, and Ellenberg's 1962 comprehensive inventory of Central European vegetation are full of photographic pictures.[99] They serve to illustrate the subjects discussed in the text, but the pictures are not, themselves, discussed. Not anywhere is a form of analysis made on the basis of photographs.

94. E. Van der Maarel, "Ordination of Plant Communities on the Basis of their Plant Genus, Family and Order Relationships," in Tüxen, *Grundfragen und Methoden* (ref. 81), 183–92.

95. L. Mucina and E. van der Maarel, "Twenty Years of Numerical Syntaxonomy," *Vegetatio* 81 (1989): 1–15.

96. E. van der Maarel and M. van der Maarel-Versluys, "Index to *Vegetatio*, Volumes 51–73, and Some Notes on the Position of the Journal," *Vegetatio* 73 (1988): 123–89.

97. E. van der Maarel, "Theoretical Vegetation Science on the Way," *Vegetatio* 83 (1989): 1–6.

98. Dierschke, "History of phytosociology" (ref. 2).

99. Braun-Blanquet, *Pflanzensoziologie*, 1st ed. (ref. 10); Heinz Ellenberg, *Vegetation Mitteleuropas mit den Alpen in kausaler, dynamischer und historischer Sicht* (Stuttgart: Eugen Ulmer, 1962).

Changes after 1980

The times were changing. In 1980, both Braun-Blanquet (aged 96) and Tüxen (aged 80) had died. After 1985 or so, the school would lose influence. Robert M. May, himself a mathematical ecologist of high reputation, in 1985 decried "the wilderness of meticulous classification and ordination of plant communities," to which Michael Crawley, another British ecologist, added that "the proliferation of multivariate techniques for the analysis of . . . plant community structure" had not led to much progress in ecology.[100] In France in particular, phytosociology suffered a crisis. One French ecologist blamed phytosociology for "blocking" British and American developments in population ecology and ecosystem ecology.[101] The Centre d'Études Phytosociologiques et Écologiques in Montpellier, by far France's largest ecological research institute and located in Braun-Blanquet's home town, was renamed Centre d'Écologie Fonctionelle et Évolutive in 1988.[102] It marked the end of a process that began when the CNRS, the French Research Council, started to withdraw support for phytosociological research. According to Jean Claude Menaut, by 2000, only "a few dinosaurs" of the French-Swiss school were still active in France, and no trace of plant sociology is said to be left.[103]

Its crisis in the Netherlands was less dramatic but still noteworthy.[104] Hanneke den Held, Westhoff's former associate in the compiling of a comprehensive overview in 1969 of Dutch plant associations, marked her distance from the school, as did Hans de Boois, who around 1980 had carried out his doctoral research in the Biesbosch supervised by Zonneveld.[105] They criticized

100. Robert M. May, "Evolutionary Ecology and John Maynard Smith," in *Evolution: Essays in Honour of John Maynard Smith*, ed. P. J. Greenwood, P. H. Harvey, and M. Slatkin (Cambridge: Cambridge University Press, 1985), 107–16, on 113; Michael Crawley, "The Structure of Plant Communities," in *Plant Ecology*, ed. M. J. Crawley (Oxford: Blackwell, 1986), 1–50, on 33; see also Van der Maarel, "Theoretical Vegetation Science" (ref. 97).

101. J. C. Lefeuvre, "La recherche en écologie en France: heur et malheur d'une discipline en difficulté," *Aménagement et nature* 97 (1990): 17–26.

102. For a description of the Centre in 1980, see the highly informative report by Richard T. T. Forman, "The Centre d'Études Phytosociologiques et Écologiques with Perspectives on American Ecology," *Bulletin of the Ecological Society of America* 61 (1980): 161–69, comparing the widely different French and U.S. research and publishing cultures in ecology.

103. Menaut, interview by author, at École Normale Supérieure, rue d'Ulm, Paris, 17 Jul 2000.

104. Through the 1970s, the school was an important presence at the botany department of the University of Amsterdam. However, after retirement, their representatives were not replaced.

105. B. Hazeleger and J. Vermaat, "Op pad met Hanneke den Held bij de Nieuwkoopse plassen," *Landschap* 27 (2010): 150–55; Hans de Boois, interview by author, The Hague, 25 Sep 1998.

plant sociology for its inability to self-critically put to the test hypotheses on the composition of plant associations.

The "defections" by Den Held and De Boois are not mentioned in the school's histories. It can be noted, however, that even when plant sociologists in France and in the Netherlands received virtually no support from their respective research councils, they were able to survive. Commissioned research for governmental projects relating to nature conservation (mostly at the level of regions and provinces) remained a source of support and at the same time a labor market for their students.[106]

Today, however, plant sociology is much less vulnerable to criticism with regard to its scientific method than it was in the 1980s. It now looks similar to several other data-oriented sciences, "big data" being among their assets. The Dutch boast of having the world's largest database of *relevés*, or vegetation plot descriptions.[107] Computer programs help identify plant associations much faster and seemingly more "objectively" than in the past. The school has managed to make a comeback and is alive and kicking in countries such as Switzerland, Italy, Hungary, Poland, the Czech Republic, and Algeria, and it continues to be an important presence in Germany. Even in France it is surviving,[108] while in the Netherlands its future seems secured. But the tables may have been turned on the old physiognomic gaze. Recently, a new adherent of the Braun-Blanquet school wrote, "The *relevé* method is burdened by much bias, subjectivity, inconsistency, arbitrariness, circular argumentation and large sampling error."[109] For the youngest generation of phytosociologists, statistical methods such as Principal Component Analysis and other forms of multivariate analysis are now a matter of course. Presently investigations are being mounted as to how the enormous databases of old *relevés*, collected over a century, can be reorganized according to more rigorous sampling criteria.[110]

106. Sources for this observation are the acknowledgment sections of books and articles by the phytosociologists.

107. J.H.J. Schaminée, S. Hennekens, and W. A. Ozinga, "The Dutch National Vegetation Database," *Biodiversity & Ecology* 4 (2012): 201–09.

108. Notably at the University of Lille, partly in conjunction with the botanical garden in Bailleul (Nord). The Muséum National d'Histoire Naturelle also continues to support phytosociological research in various ways. The Société Française de phytosociologie was founded in 2002.

109. P. Podani, "Braun-Blanquet's legacy and data analysis in vegetation science," *Journal of Vegetation Science* 17 (2006): 113–17, on 114.

110. I. Knollová, "Local and large-scale data sets and their use for vegetation classification" (PhD dissertation, Masaryk University in Brno, Czech Republic, 2005); is.muni.cz (accessed 31 Jan 2015).

Clearly, joining the big data bandwagon would offer tremendous possibilities.[111]

ISAAK ZONNEVELD: THE OBLIQUE AND THE VERTICAL VIEW

The Dutch geographer I. S. Zonneveld counts himself among the followers of Carl Troll's landscape ecology.[112] In the early part of his career, Zonneveld found an interesting amateur way to practice the "view from above." In 1963, he was hired to direct a project to make landscape surveys in Nigeria on the basis of aerial photography. Upon the completion of the project, three years later, he joined the International Training Centre for Aerial Survey (ITC) in Enschedé, Netherlands.[113] The ITC had been founded in 1950 through a special grant of the Dutch government to provide training to students from developing countries.[114] He educated thousands of students from Asia, Africa, and Latin America in Enschedé in the Netherlands in the practice of surveying from the air and establishing the identity of the ecotopes seen below.[115]

In 1981, Zonneveld gathered around him a large number of landscape geographers and ecologists at the occasion of the First International Congress on Landscape Ecology in Veldhoven, Netherlands.[116] The conference marked the foundation of the International Association for Landscape Ecology (IALE), of which Zonneveld became the first chair. The attendees were united by their interest in the practice of aerial photography and the emerging technologies of remote sensing with the help of satellites and geographic information systems (GIS).

111. On big data and its imporance for the sciences, see Christine Borgman, *Scholarship in the Digital Age* (Cambridge, MA: The MIT Press, 2007); Geoffrey Bowker, "Biodiversity Datadiversity," *Social Studies of Science* 30 (2000): 643–83; Claire Waterton, "Experimenting with the Archive: STS-ers as Analysts and Co-constructors of Databases and Other Archival Forms," *Science, Technology & Human Values* 35 (2010): 645–76.

112. Zonneveld's first personal encounter with Troll was at the occasion of a so-called Tüxen symposium in the 1960s. Zonneveld, interview by author, Enschedé, Netherlands, 29 Apr 2013.

113. Later, the International Institute for Geo-Information Science and Earth Observation; now a Faculty of the University of Twente.

114. Nil Disco, *60 years of ITC: The International Institute for Geo-Information Science and Earth Observation* (Eindhoven: Foundation for the History of Technology, 2010).

115. Zonneveld was also offered a dual appointment as professor at the Agricultural University of Wageningen. (At the time, as a non-university institute, the ITC did not yet have the right to award doctoral degrees).

116. A. Barendregt and J. A. Klijn, "Het landschap bestudeer je van groot naar klein, niet andersom. Interview with Ies (prof. dr I. S.) Zonneveld," *Landschap* 23 (2006): 161–68.

Several American ecologists, who joined IALE after the Veldhoven conference, had participated in the 1970s in the biome studies of the U.S. contribution to the International Biological Programme (IBP). The biome studies had considered very large tracts of land in a spatially quite undifferentiated manner. For the American ecologists, the landscape studies from the air marked a new turn. A U.S. chapter of IALE has been thriving since 1986.[117]

The ITC, Zonneveld's home base, had been pioneering the use of large-scale landscape photography. At the time of the conference, the ITC was building the conceptual bridge between aerial photography and present practices of remote sensing. Its methodology is different. The digital data delivered by satellites equipped with very many different measuring devices are subjected to pattern recognition by computational means. Yet, the patterns found are remarkably similar to the patches and ecotopes of the earlier aerial photography.[118]

In Zonneveld's work, like in Troll's, the visual approach to the landscape of the geographer prevailed over the more abstract analysis of the vegetational cover of the land as practiced by plant sociologists. Zonneveld was conciliatory toward phytosociology, and his stated goal was to "combine" the two outlooks. He explained the priority of the visual from his professed "holism," hence a "zooming in" from large to smaller scales.[119] This merely begs the question, however. As we have seen, different views on the causal relation between the soil and the vegetational cover may be playing out. The geographers see the vegetational cover as the visible expression of the soil, whereas plant sociologists and vegetational scientists merely rank the soil among various other "environmental factors" sustaining the structure of the vegetational cover. In Zonneveld's case, we will have occasion to revisit the technology of seeing (photography). In this first section on Zonneveld, we will study his "Dutch" work on the Biesbosch. It spans his early career, including his dissertation work, and includes his later work on the same area. The sections thereafter

117. Richard T. T. Forman, "The Beginnings of Landscape Ecology in America," in *Changing Landscapes: An International Perspective*, ed. I. S. Zonneveld and R.T.T. Forman (New York: Springer, 1990), 35–42; N. E. McIntyre, L. R. Iverson, and M. G. Turner, "A 27-year Perspective on Landscape Ecology from the US-IALE annual meetings," *Landscape Ecology* 28 (2013): 1845–48.

118. Chunglin Kwa, Mieke van Hemert, and L. van der Weij, "Visualizing Landscapes: Gestalts, Models, Pictures," in *Geospatial Technology and the Role of Location within Science*, *GeoJournal Library 96*, ed. Henk J. Scholten, R.J. van de Velde, and N. van Manen (Dordrecht: Springer, 2009), 47–58.

119. Barendregt and Klijn, "Het landschap" (ref. 116).

will focus on his survey work in Nigeria in 1963, and a project on Spitsbergen in 1977, both based on aerial photographs.

In Nigeria, and later at the ITC, Zonneveld made ample use of a photographic technique that had not yet been available to Troll: three-dimensional viewing. When two photographs are made in rapid succession, they make up a stereoscopic pair when mounted together correctly. When surveying airplanes are instructed to make pictures at required intervals, they produce series of which every pair can be used in this way. Stereoscopic viewing enables seeing depth. This greatly facilitates photo-interpretation: the identification of the topographical relief and of objects seen on the picture. It was a standard ITC practice.[120]

Zonneveld's Oblique View on the Biesbosch

In 1946, Zonneveld registered as a student at the Agricultural University of Wageningen.[121] Among his teachers were C. H. (Kees) Edelman, professor of soil science, and H. J. Venema, professor of plant sociology.[122] Before WW II, Venema had visited Braun-Blanquet in Montpellier, and now he had hired young Victor Westhoff, who would soon become the informal leader of plant sociology in the Netherlands and with whom Zonneveld, who was his first student, would have many interactions throughout his career.[123]

It was especially Edelman who deeply impressed Zonneveld, through his lectures and his maps of the soil. Theoretically, Edelman developed the concept of the "correlative complex of the landscape," while the maps showed landscape units, derived from a classificatory system based on the geological formation of the soil and its "physiographic features."[124] Edelman also showed aerial photographs of the landscape to his students. (In 1950, Edelman would be involved in the foundation of the ITC.)

120. Disco, *60 years of ITC* (ref. 114), 36.

121. Its Dutch name at the time was Rijks Landbouwhogeschool Wageningen. Zonneveld's stay there was preceded by a brief period at the Tijdelijke Academie in Eindhoven, in 1945.

122. Zonneveld interview (ref. 112). After WW II, Venema had been newly appointed to replace Jakob Jeswiet, who had been sent away for his highly visible collaboration with the Nazi occupying forces.

123. Zonneveld, interview by Mechtild de Jong, 4 Sep 1996.

124. Much later, Edelman's system would be criticized for not being sufficiently rooted in soil formation (pedogenesis); see A. G. Jongmans, M. W. van den Berg, and M.P.W. Sonneveld, *Landschappen van Nederland: Geologie, Bodem en Landgebruik* (Wageningen: Wageningen Academic Publishers, 2012), 75–76.

Zonneveld's first appointment was in 1951, just after graduating with the MSc diploma, at the Stichting voor Bodemkartering (Netherlands Soil Survey Institute), where Edelman served as director. Zonneveld's task would be researching the vegetational aspect of the soil survey. He used the results of his work for his doctoral dissertation. At the time, Zonneveld did not have direct access to aerial photography (although occasionally he could lay his hands on pictures taken from the air), but he would develop his own interesting alternative.

Oblique pictures of the landscape, however, are geographically much less exact than photographs taken vertically. They also feature considerable distortion between foreground and background. Angles may vary among pictures, making comparison difficult. Moreover, smaller objects may hide behind large objects, thereby remaining invisible. Yet, oblique pictures also have some considerable advantages: they do not require stereoscopic viewing for seeing depth thanks to their much more "natural" perspective, and they are cheaper to make.

In 1950, while still a student, Zonneveld climbed a transmission tower in the Biesbosch. The Biesbosch is a large freshwater tidal wetland, part of the combined estuaries of the rivers Rhine, Meuse, and Scheldt.[125] Zonneveld had taken refuge in the area during World War II to escape German *Arbeitseinsatz* (forced labor). With a primitive camera he made oblique photographs of its surroundings, paying special attention to a recently formed islet, a mudflat, in the meandering streams. He returned yearly, with few exceptions, and sometimes requested that friends climb the pylon to make photographs for him when he was abroad. Zonneveld made his last picture in 1997, an event that gained some media attention. A remarkable series of photographs is thus in existence, documenting the changing shape of the mudflat and the successive stages of vegetation on it. According to Zonneveld, the long time-series was possible thanks to the low-tech nature of the project.

From 1951 to 1956, Zonneveld engaged with the Biesbosch study intensely, conducting the study of the soil and of the vegetation of the area. The work

125. Zonneveld relates the conditions of hiding in the area and how he joined a local resistance group of the Landelijke dienst voor Onderduikers (LO). In 1944, the group assisted the Allied Forces in their attempt to cross the rivers during the Market Garden campaign. After the failure of Market Garden, Zonneveld was enlisted with the allied forces to defend the "Amer front" (in the Biesbosch area) and remained on active duty until the end of the war. I. S. Zonneveld, "In de schaduw van Market Garden—De Biesbosch," published on Ton Wientjen's blog devoted to the history of WW II (15 Sep 2012); www.wientjen.nl (accessed 21 May 2014).

was reported in his doctoral dissertation.[126] At the time, he did not yet identify himself as a landscape ecologist. He considered his combination of soil and vegetational studies to be unusual, that was all. Zonneveld practiced a variety of methods. With regard to the vegetational analysis, he writes that he "follows" the Zürich-Montpellier school. On a number of permanent quadrats, he conducted the *relevés* in the classical manner and computed tables on their basis, equally classical, which enabled him to identify the plant associations in the area. Yet Zonneveld makes it clear that he gives much more consideration to environmental factors than most of the adherents to the French-Swiss school, who rely on floristic analysis alone.[127]

Totally unorthodox, from the Zürich-Montpellier school perspective, is Zonneveld's presentation in his dissertation of seven pictures of the mudflat, taken from the transmission tower, representing a time-series from 1950 to 1956. The pictures document the physical growth of the island and the vegetational "succession." A vertical aerial photograph taken by the Allied Air Forces in March 1945, near the end of the war, serves as proof that the island was at that time totally sandy, devoid of any vegetational cover. On the seven pictures reproduced in the dissertation, Zonneveld marked with white dotted lines groups of plants, and identified them in the captions.

Ten years after his formal retirement and forty years after his dissertation, Zonneveld published a second book on the Biesbosch.[128] Again, he combines vegetational analysis on the ground (the permanent quadrats) and the physical environment ("the factor water"). The book culminates in the long time-series established for the original mudflat, on the basis of the photographic pictures taken from the transmission tower. On the basis of these photos, the story of plant succession is told. It is literally a story, that is, a historical account of what happened on the island. Zonneveld gives full consideration to unique events such as the arrival of single specimens of plants that subsequently determine the vegetation for a time according to the principle of first come, first serve. In some cases, these specimens arrived by themselves; in other cases, they were apparently brought to the island by human passers-by. One particular event

126. I. S. Zonneveld, *De Brabantse Biesbosch. Een studie van bodem en vegetatie van een zoetwatergetijdendelta. A study of soil and vegetation of a freshwater tidal area. 3 Volumes. Part A: Engelse samenvatting met tekstfiguren; Part B: Nederlandse tekst; Part C: Bijlagen* (Wageningen: Pudoc/Stichting voor Bodemkartering, 1960; Part A, 1960).

127. Zonneveld, *Brabantse Biesbosch* (ref. 126), 127.

128. I. S. Zonneveld, *De Biesbosch een halve eeuw gevolgd van hennip tot netelbos en verder* (Abcoude: Uniepers, 2000).

towers in importance: the closing of the estuary Haringvliet in 1970 by a dike as part of the Delta Works, to protect the Netherlands from flooding, strongly reduces tidal flow, with dramatic consequences for the ecology of the area. Other events are no less worthy of note: an unknown individual in 1973 put fire to the island. The reed survived, but the bulrush (cattail) was almost eradicated, probably providing a chance for wild celery to implant itself. In the following years, reed cutters were apparently active in the area. Zonneveld registered the events, and registered the changes in the physical environment that favored some plant species over others.

Yet much of the dynamics in the area can be understood as the result of the autonomous struggle (and cooperation) between plants. This is plant succession properly speaking. Plants change the physical environment of the area in which they grow, thereby creating the conditions of their replacement by other plants. Zonneveld cast the story of succession in terms of a struggle between plant formations. Once again, Zonneveld appears to be heterodox when compared to the Dutch members of the French-Swiss school. In the theoretical discussion of succession, in the most recent synthesis of vegetational science, it is held that, during succession, a more advanced stage "develops" gradually out of its predecessor.[129] It should be noted that for Westhoff and Schaminée, the analysis of succession from the quantitative analysis of a series of *relevés* has primacy, although they acknowledge the value of historical aerial photographs. Zonneveld, however, saw succession happening on the series of pictures taken from the transmission tower.

Zonneveld Interpreting Aerial Surveys

In 1963, Zonneveld entered the service of the United Nations Food and Agricultural Organization (FAO) for an aerial survey project in Northwestern Nigeria. The next three full years, Zonneveld, with two Dutch fellow scientists and Nigerian staff, produced a colored map (1:500,000) of the region, the Sokoto and Rima river basins, which, through its identification of the land units of which the region was comprised, would be ultimately helpful in developing the region. The map was compiled from aerial photographs (1:10,000 and 1:40,000), made in 1959 and 1962 by Hunting Aerosurveys at

129. V. Westhoff, J.H.J. Schaminée, and A.H.F. Stortelder, "Vegetatiedynamiek," in *De vegetatie van Nederland 1: grondslagen, methoden en toepassingen*, ed. J.H.J. Schaminée, A.H.F. Stortelder, and V. Westhoff (Uppsala and Leiden: Opulus Press, 1995), 193–210, on 204.

the request of the Nigerian government. Combined with field studies on the ground, they yielded so-called aerial photo mosaics.[130] Zonneveld was residing at the time in Sokoto, the regional capital, from where he and his team made altogether ten expeditions in several Russian jeeps, each expedition one to three weeks in duration. Zonneveld had equipment for the stereoscopic reading of the aerial photographs at his home in Sokoto.

The work order was as follows. First, a so-called preliminary photo-interpretation was carried out with the help of a stereoscopic viewing of the aerial photographs. Several land-patterns were inferred, one of which had the visual appearance of a dune landscape. The stereoscopic study revealed the landscape to be much flatter than first thought, hence its designation as a "pseudo-dunes and gulleys pattern." Subsequent fieldwork included geological, geomorphological, soil, and vegetational analysis. While on field expeditions, the team took the aerial photographs with them, using a pocket stereoscope, a practice that once more underscores the importance of photographs over and above any diagrammatical rendering. One of the local staff members, an imam, made botanical identifications.[131] When rivers had to be crossed, a particularly tall staff member carried the aerial photographs on his head.

Reconstruction of the geological history of the area led to what the authors call "a theory," namely that originally the area had been a desert (apparently a southward extension of the Sahara) on which real dunes had formed. In later times, dune tops were leveled, dune valleys were filled in, and while in the former dune valleys a richer vegetation with trees and shrubs developed, the former dune tops would feature savannah-type vegetation.

Thus, the aerial photographs guided the analysis of the landscape. Visual characteristics prevailed in the choice of sample areas on the ground. Once soil samples had been taken (which were sent for analysis to the Netherlands), Zonneveld applied a Braun-Blanquet-derived ordination method, that is, using tables to sort out various soil types. Zonneveld's reports of the Nigeria project show a variety of maps, diagrams, aerial photographs with lines drawn on them, and pictures made with an ordinary camera on the ground. In all cases, the pictures are carefully explained and form an integral part of the argument.

130. W. G. Sombroek and I. S. Zonneveld, *Ancient Dune Fields and Fluviatile Deposits in the Rima-Sokota River Basin (N.W. Nigeria)*, *Soil Survey Papers no. 5* (Wageningen: Netherlands Soil Survey Institute, 1971), on 22; I. S. Zonneveld, P. N. de Leeuw, and W. G. Sombroek, *An Ecological Interpretation of Aerial Photographs in a Savanna Region in Northern Nigeria* (Enschedé: ITC, 1971).

131. Zonneveld interview (ref. 112).

The Svalbard Expedition of 1977

In the summer of 1977, Zonneveld had two Dutch MSc students make a landscape ecological map of Edgeøya, the third largest island of the Svalbard archipelago, just east of Spitsbergen, Norway, and around the size of Trinidad (5,000 km²). They traversed the island on foot and were, at regular intervals, provided with food dropped from a small aircraft, in polar bear-proof cans. The Norwegian Polar Institute had provided 200 aerial photographs made in 1971. A preliminary photo-interpretation was carried out in Enschedé before departure. Vegetational *relevés* were taken on the entire island with reference to the method of stratified sampling.[132] Twenty-one sample areas were designated. Cut-outs of the photographs, along with the markings of their preliminary interpreation, served as visual controls. On each of the sample areas, between seven and sixteen sample points of *relevés* were to be selected on the ground, balancing stratification criteria and random sampling. For the *relevés* themselves, the Zürich-Montpellier arithmetic was used, here with plot squares of between 70 and 300 m². By the end of the short summer (two months in duration), snowfall started. Only eleven sample areas only were completed, with a slightly higher number of *relevés* in each. This was deemed sufficient to prepare the land unit map of the entire island, on a scale of 1:200,000, again on the basis of the aerial photographs and the data collected on the ground. Zonneveld would use the hand-drawn, hand-colored map for many years in presentations and lectures. When it finally became worn, he found funding to have the map published, along with an English translation of the original Dutch report, explaining the remarkable time-lapse between the fieldwork (1977) and final publication of the Edgeøya results (2004).[133]

Zonneveld and the Braun-Blanquet School

The Dutch "chapter" of the Zürich-Montpellier school, to this day, generously includes Zonneveld as a member of their community in their several long histories of the school.[134] Westhoff was considered the informal leader of the

132. I. S. Zonneveld, Max Lebouille, and Niels de Nies, "Landscape ecology ('land unit') map of Edgeøya, Spitsbergen with emphasis on vegetation," in N. Boschman and L. Hacquebord *Permanence in Diversity: Netherlands Ecological Research on Edgeøya, Spitsbergen* (Groningen: Bakhuis Publishing, 2004), 103–62.

133. Max Lebouille, personal communication, 15 Jun 2015.

134. Westhoff, Schaminée, and Sýkora, "De geschiedenis" (ref. 2); V. Westhoff and J.H.J. Schaminée, "Plantensociologie in Nederland in biohistorisch perspectief: onderzoekers in

school after 1943 until his death at the age of 84 in 2001. Schaminée gradually took over informal leadership in 1995, when a multi-volume overview of the vegetation of the Netherlands was published, for which Zonneveld was invited as co-author.[135]

Zonneveld's method of aerial identification of vegetational units was briefly acknowledged in some of the internal histories of the school, but no attempts were made at integration on the part of the phytosociologists.[136] They never even addressed it as an issue. Within the school of plant sociology, Zonneveld thus remains the odd man out. He juggled with the same problem as Carl Troll some decades before him. The theoretical reconciliation with the phytosociologists, desired by Zonneveld, was not achieved. Sometimes, opposing points of view were exchanged. Zonneveld recalls his astonishment when on a field trip near the lakes in low-lying Holland with Sam Segal, a more orthodox plant sociologist, he found out that Segal refused to identify the reed as a unit of vegetation.[137]

While Zonneveld, after the completion of the Nigerian project, continued to carry out consultancy projects in Africa and Asia based on aerial surveys, he also reflected on his methodology, now basing himself on "the method of stratified sampling." Preliminary photo-interpretation of aerial photographs, according to Zonneveld, would provide "an objective base for stratified sampling." Because the units identified on the basis of the photographs are large,

> these units . . . are delineated on the photo without knowledge of the details as far as floristic and micro-structural aspects are concerned. So *there is no possibility for a bias*, because the items to be treated statistically are unknown at the moment of selecting the sample areas. This is in contrast to the case where selection is done in the field.[138]

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onderlinge samenhang," in *100 jaar op de knieën. De geschiedenis van de plantensociologie in Nederland*, ed. J.H.J. Schaminée and R. Van 't Veer (Noordwolde: Opulus Press, 2000), 54–127.

135. A.H.F. Stortelder, J.H.J. Schaminée, and I. S. Zonneveld, "Vegetatiekartering," in *De vegetatie van Nederland 1: grondslagen, methoden en toepassingen*, ed. J.H.J. Schaminée, A.H.F. Stortelder, and V. Westhoff (Uppsala and Leiden: Opulus Press, 1995), 211–24.

136. Sam Segal, "Vegetation Science," in *Handbook of Contemporary Developments in World Ecology*, ed. E. J. Kormondy and J. F. McCormick (Westport, CT: Greenwood Press, 1981), 245–51.

137. Zonneveld interview (ref. 112). For Segal the reed was a dominant species, hence not suitable to define plant associations.

138. I. S. Zonneveld, "Aerial Photography, Remote Sensing and Ecology," in *Proceedings of the First International Congress of Ecology* (Wageningen: Centre for Agricultural Publishing and Documentation, 1974), 278–82 (emphasis added).

In 1988, Zonneveld argued once more against the phytosociologists' methods of sampling the vegetation:

> The solution is the aerial photograph. Photo-interpretation provides, in the first stage of survey, a rather *objective* analysis of the land. This results in delineation of physiographic (landscape) units.[139]

In fact, without literally saying so, Zonneveld had practiced this view much earlier than appears here in writing, probably since the early 1960s, and indeed, as we have seen, in the few pages in his doctoral dissertation on the vegetational succession on the mudflat in the Biesbosch.

As mentioned above, phytosociologist Eddy van der Maarel had also invoked "stratified sampling" to justify the "subjective" selection of plots for *relevés*. Although Zonneveld did not justify his own version of stratified sampling any further, it seems that he was directing himself against Van der Maarel, claiming objectivity for himself in a manner that Van der Maarel could not. The study of the vegetation of Spitsbergen, carried out in 1977, marks the self-conscious application of Zonneveld's methodology of stratified sampling. Later, Zonneveld mentioned the Nigeria and the Spitsbergen studies on equal footing as expressions of his approach to landscape research.[140]

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Whatever the precise meaning of "subjective" and "objective," it is clear that Zonneveld claims a different epistemic status for his visual units, compared to the "homogeneous" stands of the phytosociologists. The landscape geographers first established the spatial distribution of the ecotopes on the basis of the aerial photographs, hence "objectively," and then went on to identify what they were in terms of floristics and geology. Identification was carried out on the ground, a process not different from what much later, in the era of remote sensing imagery from satellites, would be called "ground truthing."[141]

139. A. W. Küchler and I. S. Zonneveld, "Floristic Analysis of Vegetation," in *Vegetation Mapping* (Dordrecht: Kluwer, 1988), 51–65, on 56 (emphasis added). The article identifies Zonneveld as the author of pages 51–56.

140. Zonneveld interview (ref. 112).

141. The term "ground truthing" came into common usage after 1970.

At least in part the claim rests on what can be termed the "mechanical objectivity"[142] of aerial photography. Over large stretches of land, pictures were made with exactly similar technical specifications, by firms such as Hunting Aerosurveys, Hansa Luftbild, and KLM Aerocarto. These firms had standard ways of making aerial surveys for a variety of mapping purposes. In the photographic process, distance, lens, and film achieve a first stage of abstraction in the rendering of the landscape, through which the various landscape elements or ecotopes are somewhat reduced to types.

However, it is the angle of vision of the camera, together with scale, that does most of the work. The oblique and vertical views give pictures of the landscape with either a very high horizon or no horizon at all. Thereby, they *produce* the "smallest units of landscape." The mosaic structure of different ecotopes springs forth seemingly naturally from the aerial photographs, and it has done so since the early 1920s. The ecotopes were transferred to the early forms of remote sensing images made at the ITC since 1970 or so.[143] By the twenty-first century, the smallest units of landscape are still being reproduced in digital imagery made with current remote-sensing equipment. We may note that Zonneveld was one of the early users of remote sensing data, which for him was an extension of aerial photography. In a word: aerial photography has given landscape ecology a new gestalt of the natural landscape, in a way that was previously not available.[144]

Troll and Zonneveld both pledged their allegiance to an organismic holism. Ultimately, however, the patchy landscape they had discovered made them redefine that notion. After 1975, dynamic views of the landscape emerged, theorizing links and exchanges between the patches. Zonneveld himself located holism and homeostasis at the level of the landscape units themselves instead of at the landscape as a whole, and he also revamped homeostasis as a far-from-equilibrium concept.[145] Richard Forman, an American geographer present at the Veldhoven conference, would tie himself into a typical metaphor of the current age: the network.[146] He notably theorized the notion of corridors, serving to link the patches. Ecologist Herman H. Shugart, too, motivated

142. Daston and Galison, *Objectivity* (ref. 13).

143. Disco, *60 years of ITC* (ref. 114), 57.

144. Kwa, "Painting and Photographing" (ref. 1).

145. Zonneveld, "Land Unit" (ref. 54).

146. Richard T. T. Forman, "Interaction among Landscape Elements: A Core of Landscape Ecology," in *Perspectives in Landscape Ecology: Proceedings of the International Congress Netherlands Society for Landscape Ecology, Veldhoven 1981*, ed. S. P. Tjallingii and A. A. de Veer (Wageningen:

the fragmented nature of the landscape by an appeal to the view from the air. He would develop a yet more dynamic view of ecosystems, in which patches in the landscape replace each other over time.[147] A landscape, then, emerges out of novel combinations of an ultimately limited set of landscape elements, calling into mind a baroque conception of complexity.[148]

With regard to the phytosociologists, we have outlined so far in this article what divided them from the geographers. The gestalt of the patchy landscape did not impose itself on the phytosociologists, as they stayed on the ground. When they did rely on a visual apprehension of the homogeneity of the various floristic stands, it was based on their "trained judgment."[149] They admitted to its "subjectivity." The label "objective" remained reserved for plant counting and for multivariate analysis. We may see it as the "structural objectivity" discussed by Peter Galison and Lorraine Daston.[150]

Yet, the similarities between them cannot be overlooked. Troll and Zonneveld may have been "zooming in" on the landscape from the larger picture from above, but starting from the preliminary photo interpretation, they built the landscape up from the ecotopes they had identified. The phytosociologists, in their part, started with the plant associations. In their system of classification the associations were the smallest units of vegetation, indeed smaller than the smallest units of landscape of the geographers. They understood the plant association itself as a theoretical entity, namely through the metaphor of the table companions. But with the data of the *relevés* in hand, the phytosociologists shifted gears from a hypothesis-driven to a taxonomical rationality and operated on a logic of abstraction and classification.[151] Beyond plant

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Pudoc, 1982), 35–48; Richard T. T. Forman, *Land Mosaics: The Ecology of Landscapes and Regions* (Cambridge: Cambridge University Press, 1995).

147. Henry H. Shugart, *Terrestrial Ecosystems in Changing Environments* (Cambridge: Cambridge University Press, 1995).

148. Chunglin Kwa, "Romantic and Baroque Conceptions of Complex Wholes in the Sciences," in *Complexities: Social Studies of Knowledge Practices*, ed. John Law and A. Mol (Durham, NC, and London: Duke University Press, 2002), 23–52.

149. Daston and Galison, *Objectivity* (ref. 13).

150. Ibid. Neither Braun-Blanquet nor Tüxen claimed "objectivity" for the associations, but some of their opponents, the "mathematicians," in 1970 did (see above). Some physicists may balk at conferring the notion of structural objectivity, i.e. objective mathematical structures, at elusive ecological objects such as the plant association. But there could be going a bit of platonist essentialism into the concept of the (abstract) association of which the association in the field is but a concrete instantiation. See also the discussion of "type" in ref. 79.

151. Chunglin Kwa, *Styles of Knowing: A New History of Science from Ancient Times to the Present* (Pittsburgh: The University of Pittsburgh Press, 2011).

associations, they worked toward larger plant units, formed through further abstraction. Ultimately, mechanical objectivity, subjective expert judgment, and structural objectivity all served the same goal: building a landscape inductively from a taxonomy of its constituent fragments.

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