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Some climatic relationships of the vegetation of Argentina, in global perspective

Einige klimatische Verhältnisse der Vegetation Argentiniens in globaler Betrachtung

Consideraciónes globales sobre algunas condiciónes climáticas de la vegetación argentina

by

Elgene O. BOX

CONTENTS

1. INTRODUCTION

Study of vegetation-climate relationships in Argentina, at least by foreigners, has often been dominated by the "pampa problem", i.e. why an apparently natural grassland should occur in what appears to be a humid, forest climate. This and similar questions arose out of attempts to fit Argentina (and indeed the whole world) into world vegetation classifications based on stated or supposed climatic relationships. Perhaps most recently, in a world study of the climatic relations of plant growth forms (BOX 1981, hereafter called T:VS1 = Tasks for Vegetation Science, vol. 1), Argentina again appeared, perhaps erroneously, to be problematic.

One of the main causes of such problems in Argentina was the use of bioclimatic indices which do not accurately reflect the actual water balance over large parts of Argentina, perhaps especially the pampas. This includes the THORNTHWAITE-MATHER (1957) formula for potential evapotranspiration* (PET), which may underestimate by up to 20% at this latitude, and various pan evaporation methods, which probably overestimate by similar amounts.

The pampa situation is now better understood, thanks to efforts such as those of PARODI (1940, 1942), ELLENBERG (1962), PAPADAKIS (1965), WALTER (1967), BURGOS (1968, 1970), CAPPANNINI (1968), LEWIS et al. (1974-1980), FRANGI (1975), and LEON and ANDERSON (1983) who attempted to integrate the climatic, edaphic, hydrologic, and biological aspects of the question. Finally, in October-November 1983, the International Phytogeographical Excursion came to northern Argentina. This provided an opportunity for foreigners, some with global interests, to check various hypotheses under the expert guidance of local field botanists, not only in northern Argentina but also near Córdoba and Mendoza, and in the southern Andes, Patagonia, and Tierra del Fuego.

If plant bioclimatology has any value at all (and some pure botanists would say that it does not), then it must find general principles and

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*PET is used, rather than Ep (potential evaporation), in order to distinguish evapotranspiration from vegetated surfaces and evaporation from open-water or other non-vegetated surfaces.

some global relationships, based on global "common denominators." One such necessary basis is a reliable, world-applicable estimate of the climatic water balance. Because it represented a rigorous, global comparison of the implications of climate-based hypotheses versus actually occurring vegetation, T:VS1 was a step in this direction. If it failed in Argentina and certain other areas, this was perhaps due to questionable, Northern Hemisphere estimates of PET. The next step, then, is to improve the PET basis, re-do the vegetation "predictions", and re-interpret the results. At the same time this may also provide some improved understanding of Argentine vegetation in relation to that of other continents.

The purpose of this paper is threefold:

1) To compare the performance of PET estimators in Argentina and find an improved water-balance index. (Which moisture index works best in Argentina while also permitting reliable worldwide comparisons?)
2) To compare the climatic relationships of Argentine vegetation types which those elsewhere. (Does Argentine vegetation follow the same bioclimatic rules as the rest of the world?)
3) To identify perhaps unusual occurrences or absences of particular plant types in Argentina, based on their expected climatic affinities. What unusual forms and what open "niches" might exist in Argentina?)

This last component may raise questions for future study.

The methodology involves comparison of hypothesized bioclimatic boundary values against existing or hypothesized "natural" vegetation regions, an approach which is complicated immediately in the pampa region by our lack of knowledge (or agreement) on the original condition of the pampa. Perhaps one must distinguish initially between forested (i.e. closed forest) and wooded (e.g. open woodland, groves, or savanna) concepts of a pampa with trees. Nevertheless, it is not necessary to assume either a wooded or treeless pampa in order to judge an improved water- balance index, since earlier bioclimatic boundaries (including Thornthwaite) fell so far to the west. One need only assume that the original pampa was not a dense, closed forest (except perhaps along the coast), and most observers seem to agree on this.

Some have argued that vegetation "predictions" are superfluous when the natural and actual vegetations are generally known. Of course such "predictions" are only a means of hypothesis testing; it is really the underlying bioclimatic relationships (if they exist) which are important. Are they consistent with those elsewhere? Results from these and other questions permit us to approach vegetation from several different perspectives: local intensive fieldwork, general principles of plant-environment relationships, and ecological attempts to integrate and understand structure-functional relationships.

AGRECIMIENTO

Quiero expresar mi agradecimiento sincero al profesor y a la señora Eskuche así como también a muchos otros colegas por su organización esplendida de la Excursión. Muchas gracias también a los colegas que siempre dieron respuestas a mis preguntas interminables sobre las variaciones estacionales de las plantas.

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I would like to thank Professor and Señora Eskuche (L. Zulema Ahumada) for their splendid organization of the Excursion. Thanks also to many other Argentine colleagues who were so helpful in the field, with the organization, and who sent information after the Excursion.

2. THE "PAMPA PROBLEM"

Climatic descriptions of Argentina were available relatively early (e.g. DAVIES 1910). Since that time various attempts have been made to explain the pampa grassland by estimating the location of the hypothetical bioclimatic boundary (annual precipitation = PET) between the humid, potentially forest climate and the dry, potentially non-forest climate. BURGOS and VIDAL (1951), WALTER (1967) and BURGOS (1968, 1970) described the use of various moisture indices in the pampa region, including those of KOEPPEN (1931), HOLDRIDGE (1947), LAUER (1952), GAUSSEN (1954), BUDYKO (1956), THORNTHWAITE and MATHER (1957), and WALTER and LIETH (1960-1967). Most indices apparently underestimate the potential evapotranspiration and thus leave the potential forest limit too far west.
PAPADAKIS (1965) explained various complicating effects on PET rates (e.g. vegetation type, oasis effect) and adapted the PENMAN (1948) formula to reflect the non-linear effect of daytime maximum temperatures on evaporation. Finally, WALTER (1967) compared moisture-balance estimates

by several formulas, plus pan evaporation data and field observations of pond salinization, to conclude that the annual water balance of most of the pampa is indeed negative, with deficits increasing southward and westward from near zero at Buenos Aires to 600 mm at Trenque Lauquen and 800 mm at Bahia Blanca (see Figure 1 for locations). WALTER concluded that the eastern pampa represents a sub-humid climate corresponding to those of the Russian meadow-steppe and the North American prairie, albeit with a much less continental temperature regime.

BURGOS (1968, 1970), using an earlier but similar version of HOLDRIDGE's (1959) PET formula in combination with his life-zone system (1947), also found much of the pampa region to fall on the sub-humid side. BURGOS (1970, p. 78) concluded that Holdridge's water-balance formula was "more in accord with experimental observations" and moved the humid-dry climatic boundary much further east, leaving only the eastern half of Corrientes province and easternmost Buenos Aires province in the humid region. Burgos and others have also considered the seasonal aspects of the pampa climates. For example, it is often thought that the summer drought of temperate grassland regions precludes the establishment of tree seedlings, thus giving grasses the advantage and pushing the grassland-forest boundary to the humid side of the humid-dry climatic boundary (without even any reference to fire, which has the same effect). Such seasonality factors should be investigated bioclimatically but are not necessary for the present purpose.

The above explanations, combining climatic theory and field observations, seem convincing. They do not invalidate other phytoclimatic models, such as those of THORNTHWAITE or WALTER, but mean that these must be used with PET estimates more accurate locally than those perhaps originally suggested by those authors. Note that, as already stated, we do not need to make any judgments concerning the original condition of the pampa, i.e. with or without trees. Trees can occur, in progressively more open stands, well to the dry side of humid-dry climatic boundaries, as seen in many areas (e.g. the Argentine chaco).

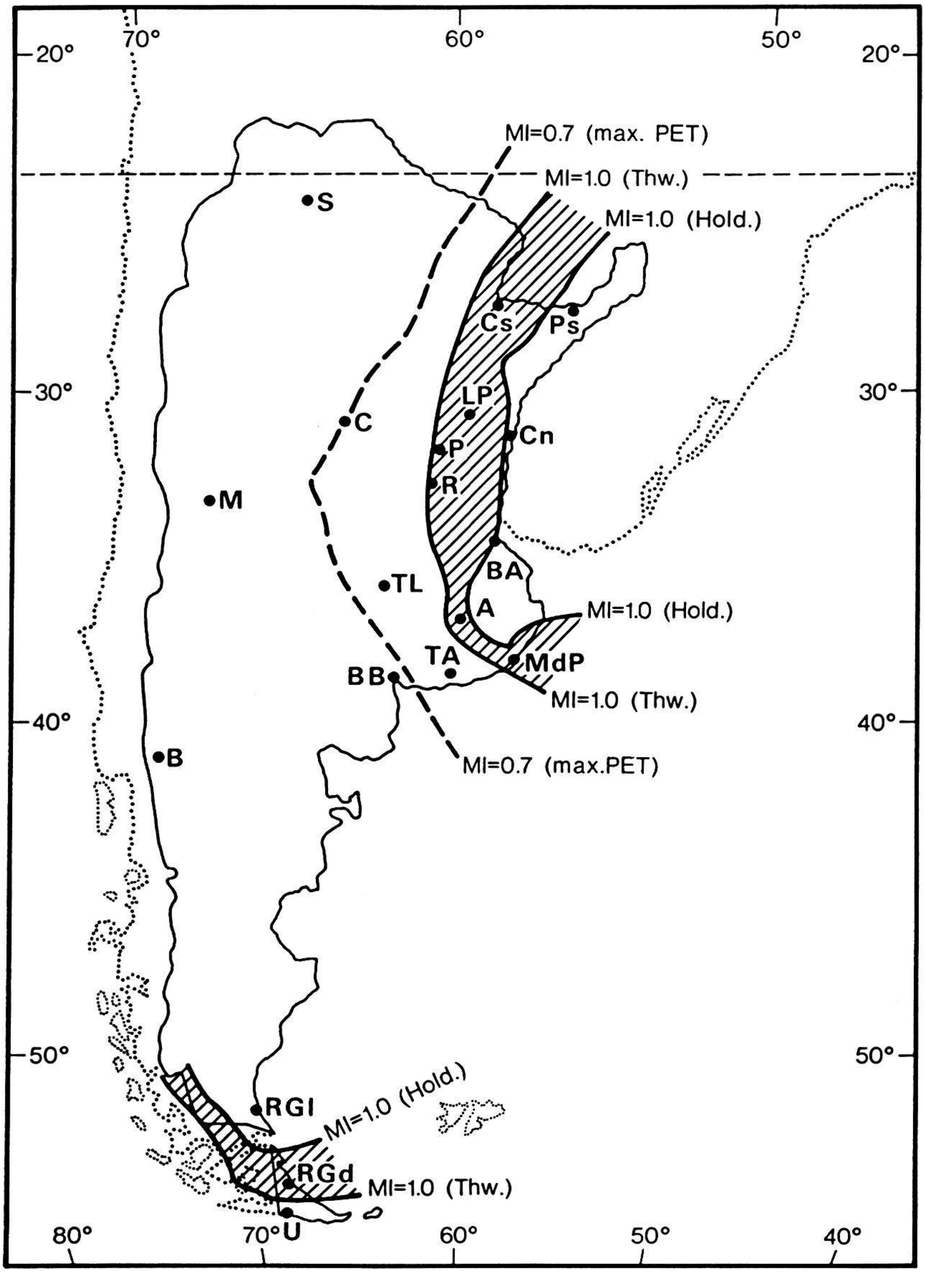

Fig. 1. Humid-Dry Bioclimatic Boundary Estimates in Argentina, based on the annual moisture index (MI)

Abb. 1. Schätzungen der bioklimatischen Grenzen zwischen feucht und trocken in Argentinien aufgrund des Jährlichen Feuchte-Index (MI)

Fig. 1. Los límites bioclimáticos entre humedo y seco en la Argentina estimados en base al índice anual de humedad (MI)

3. GLOBAL MOISTURE INDICES

The search for global relationships, yielding reliable bases for comparisons of different regions, requires inclusion of all different relevant situations within the data-bases to be used for model development. In vegetation-climate studies this means comparison of water-balance indices against vegetation patterns over the full spectrum of climate and vegetation types found in the world. Precipitation data are readily available but PET measurements are few and problematic, so the PET needed for water-balance indices must generally be estimated from other climatic data.

An excellent review of available moisture and other bioclimatic indices is given by TUHKANEN (1980). For global work involving many data sites, however, one must have a PET estimation method which:

Fig. 1 (continued - Forts.)

The map shows regions of discrepancy (diagonal shading) between Thornthwaite and Holdridge estimates of humid-dry bioclimatic boundaries, as defined by the MI=1.0 isoline. The Thornthwaite estimate is also similar to other, early bioclimatic estimates in the pampa region (see main text). Much of the pampa region and of Tierra del Fuego fall into these disputed transitional areas. In both cases, the MI=1.0 isoline based on the higher estimate of potential evapotranspiration (Holdridge in the north, Thornthwaite in the south) appears to coincide better with actual vegetation patterns. The MI=0.7 isoline (based on maximum PET, i.e. on Holdridge in the north) coincides fairly well with the southwestern limit of the drier pampa grasslands. These results are consistent with those from other continents.

Locations (and provinces):

A = Azul (Buenos Aires prov.)
B = Bariloche (Rio Negro)
BA = Buenos Aires
BB = Bahia Blanca (Bs.As.)
C = Cordoba
Cn = Concordia (Entre Rios)
Cs = Corrientes
LP = La Paz (Entre Rios)
M = Mendoza
MdP = Mar del Plata (Buenos Aires)
P = Paraná (Entre Rios)
Ps = Posadas (Misiones)
R = Rosario
RGd = Rio Grande (Tierra del Fuego)
RGl = Rio Gallegos (Santa Cruz)
S = Salta
TA = Tres Arroyos (Bs.As.)
TL = Trenque Lauquen (Bs.As.)
U = Ushuaia (Tierra del Fuego)

In addition, the southern part of Argentina (south of about 40°S) is called Patagonia, while the "chaco" region extends from northernmost Argentina northward through Paraguay and into southeastern Bolivia.

1. can be calculated everywhere (i.e. from climatic data which are readily available everywhere); and
2. is relatively accurate and consistent throughout the world.

Only mean monthly air temperature and precipitation data are available for almost all areas, so we are limited immediately to mean-air-temperature PET methods, mainly those of THORNTHWAITE and MATHER (1957) and HOLDRIDGE (1959, not 1947). Various studies have shown that the Thornthwaite method, based mainly on data from the USA and Canada, grossly underestimates PET in the tropics, subtropics, and much of the Southern Hemisphere temperate zone (e.g. DAMAGNEZ et al. 1963, PAPADAKIS 1965, WALTER 1967, BURGOS 1970). Even in the southern United States, Thornthwaite PET appears to be too low already (STEPHENS and STEWART 1963). On the other hand, there are some suggestions that Holdridge's PET estimates, based mainly on Neotropical data but otherwise with a superior theoretical basis, unterestimate PET at high latitudes, due perhaps to lack of daylength and wind factors (e.g. TUHKANEN 1980).

In order to resolve this discrepancy, BOX (1979, world map no. 7) computer-mapped the difference between the Thornthwaite and Holdridge PET estimates for 1300 sites worldwide and found that they generally coincide only in a band along about 40^{o} N latitude (plus other widely scattered individual sites). Thornthwaite is higher over the large land area of the northern temperate and polar zones, while Holdridge is generally higher throughout the tropics and subtropics of both hemispheres. These relative values do not prove relative accuracy but are consistent with other evidence of under/over-estimation. Thus, in order to have a single method which may be more reliable everywhere, one might compute both estimates and simply take whichever is larger at the particular site (hereafter called "higher PET"). This is not very satisfying, but it does at least usually select the method based on the locally more appropriate data basis, tropical versus temperate. Of course, even within their own appropriate regions, both formulas may over- or under-estimate due to lack of a humidity factor. Such a factor could probably be devised, using only available precipitation and temperature data, and may improve these PET formulas. For now, however, the above "higher PET" basis may represent the best water-balance basis we can find for global comparisons until a more geographically reliable, comprehensive model is developed.

4. WATER-BALANCE REGIONS IN ARGENTINA

Since we are looking at Argentina in global perspective, we look for climatic indices which reflect vegetation patterns in Argentina but which also are directly useable in all other parts of the world. We thus cannot use some of the measures which have been applied or developed in Argentina, due to their regional parameterization and/or greater data demands. One may have to sacrifice some local accuracy in order to make world comparisons, but this is a familiar geographic problem.

Perhaps the best test of the accuracy of a climatic index is to examine it where the vegetation is most sensitive to its variation. For an annual moisture index defined as MI = precipitation/PET, this would be in the range from MI = 0.7 to a little over 1.0, with MI = 1.0 representing the hypothetical boundary between humid and dry climates.* Although grasslands have expanded well beyond their climatic limits due to fire and other disturbances, MI = 1.0 (or a bit less) correlates fairly well with transitions between naturally closed forest and regions of more open woodlands, grasslands, or savannas in other temperate areas (e.g. BUDYKO 1956, MATHER and YOSHIOKA 1966), provided that the MI estimate is reasonably accurate. In Argentina there are three general areas of forest-grassland or forest- scrub ecotone, in which the MI = 1.0 isoline might be expected to fall: in the pampa and adjacent chaco region, across Tierra del Fuego, and along the eastern base of the Andes (at least in the south). The methodology employed here, then, is to examine different combinations of THORNTHWAITE and HOLDRIDGE PET and MI values in these areas in order to see which appears to correspond best to vegetation patterns (within the limits imposed by varying opinions of original vegetation cover).

In his 1967 study, WALTER provided values of precipitation, PET (estimated by the Thornthwaite and the 1957 Papadakis methods), and pan evaporation in the pampa and adjacent regions (two different tables). These data are combined in Table 1 and compared with Holdridge PET and MI estimates (based on temperature data from WILLMOTT et al. 1981, which represent comparable measurement periods, generally before 1950). The

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* Note that THORNTHWAITE's Im=MI-1.0 and that HOLDRIDGE's (1959) run-off ratio (= PET/precipitation) = 1/MI.

Holdridge PET estimate is greater than that of Thornthwaite for all 12 sites, while the Papadakis PET estimates are generally even higher (and MI lower) but still less than measurements of open pan evaporation, as might be expected. Holdridge MI values are at or above one only along the coast and at Azul (slightly higher precipitation), and all MI values generally decrease westward and southward (see Figure 1 for locations). These results are quite consistent with other studies and with reports of an earlier narrow strip of woodland or forest islands along the coast (PARODI 1940). These Holdridge-based MI values also correspond to MI values in temperate forest-grassland ecotone regions on other continents.

Table 1. Estimates of Potential Evapotranspiration (PET), Pan Evaporation (PE), and Annual Moisture Index (MI) in and near the Pampas Region.

Tab. 1. Geschätzte potentielle Evapotranspiration (PET), potentielle Verdunstung (PE, Tank Typ A) und jährliche Wasserbilanz (MI) in und in der Nähe der Pampa-Region.

Tab. 1. Estimación de la evapotranspiración potencial (PET), evaporación potencial (PE, tanque tipo A), y balance anual de agua (MI) en la Pampa y sus alrededores.

HOLDRIDGE (1959) PET estimates are given for pampa sites from two tables in WALTER (1967). Precipitation values are from WILLMOTT et al. (1981) or from WALTER (in parentheses) if given; there is sometimes considerable variation between precipitation amounts. Thornthwaite PET estimates are from WALTER (in parentheses) or based on the Willmott data. PAPADAKIS (1957) PET and pan PE values are from WALTER's tables. Holdridge PET values are calculated from the Willmott temperatures. MI values use Holdridge PET but show ranges based on the different precipitation data (WALTER in parenthesis).

Location	Precipitation	Potential Evapotranspiration Thornthw.	Papadakis	Holdridge	Pan PE	Moisture Index (Holdridge)
Azul	(816)-(856)	712-(719)	(970)	813	1280	(1.0)-(1.05)
Bahia Blanca	539-(540)	(780)	1161	918	-	0.59
Buenos Aires (observ. central)	957-(1001)	786	-	949	1000	1.01-(1.05)
Corrientes	(1204)-1231	(1000)	1324	1262	-	(0.95)-0.98
Cor. Suarez	682-(746)	695	-	773	1140	0.88-(0.96)
Junin	904-(932)	800	-	961	1160	0.94-(0.97)
La Plata (Los Hornos)	(996)-(1076)	(800)	(815)	-	1080	- - -
Mar del Plata	729-(941)	691	-	796	1200	0.92-(1.18)
Mercedes	(1053)	-	-	-	1160	- - -
Paraná	(900)-969	(900)	1077	1097	-	(0.82)-0.88
Trenque Lauquen	(740)-770	795	-	938	1340	(0.79)-0.82
Tres Arroyos	(694)-695	(750)	1034	826	-	0.84

In order to map estimated MI isolines throughout Argentina, monthly temperature and precipitation data for 150 sites were collected, mainly from WILLMOTT et al. (1981). Thornthwaite, Holdridge, averaged-PET, and higher-PET estimates of the annual moisture index (MI) were then computer-mapped. This low site density does not permit any reasonable attempt to map isolines in the Andes, but results for the pampa-chaco region and for Tierra del Fuego are summarized in Figure 1.

In the north, the Holdridge MI isoline (= higher-PET isoline) runs farthest east, appears most consistent with the recent grassland vegetation, and coincides generally with BURGOS (1968, 1970) and PARODI (1940). The MI=0.7 isoline (higher-PET basis, i.e. Holdridge) is also included in Figure 1 and corresponds well with the western limit of pampa grasslands presented by LEON and ANDERSON (1983). Further north, in the more seasonal eastern chaco, however, forests also occurred at MI values down to around MI = 0.7 (now degraded to open scrub). Such chaco forests (sometimes lower, more open woodlands) were possible at lower MI values due perhaps to the reliability of the tropical-subtropical summer rainy season and the depth of tree root systems. This lower MI-limit for tropical and subtropical deciduous forests can also be seen on other continents (BOX 1981).

In the south, on the other hand, it is the Thornthwaite method which gives the higher PET estimates (lower MI) and whose MI = 1.0 isoline appears to coincide better with actual vegetation patterns. Only the southern part of Tierra del Fuego is forested, the northern part being a windy, less arid extension of the Patagonian steppe (see, for example, the map in CABRERA 1978). This higher PET estimate by Thornthwaite is consistent with most other results from high-latitude regions and with the map of BOX (1979). It thus appears that the "higher PET" basis suggested earlier, which generally selects Holdridge at lower latitudes and Thornthwaite at higher latitudes, is an improvement which will permit more reliable local work and regional comparisons, in Argentina and worldwide. This inelegant patch, however, is certainly not the final answer. A better, world-applicable PET estimator is still badly needed.

Annual MI for 36 sites in the humid-subhumid ecotonal regions of Argentina, based on the four PET combinations mentioned above, are compared in Appendix B. Using always the higher-PET basis for MI, one can find reasonable relationships between annual climatic water balance and natural vegetation cover throughout the three ecotonal regions of Argentina. This does not prove any bioclimatic relationship but does suggest "higher PET" as an index which shows less variation in its accuracy from region to region. These MI relationships in Argentina, based on "higher PET", are similar to corresponding situations on other continents, including the much more continental forest-grassland ecotone regions of the northern temperate zone.

5. MODELING PLANT-CLIMATE RELATIONS

The logic of relationships between climate and plant form has been stated (e.g. VON HUMBOLDT 1807, TROLL 1960, MOONEY 1974, BOX 1981, 1984)

Table 2 (p. 193) Climatically expected potential growth-form composition of the vegetation near Corrientes (city), northern Argentina.
Tab. 2 (S. 193) Klimatisch erwartete potentielle Zusammensetzung (Wachstumsformen) der Vegetation um Corrientes (Stadt), Nordargentinien.
Tab. 2 (p. 193) La composición de la vegetación cerca de Corrientes (ciudad) como se espera según el clima.

The predicted vegetation profile (model T:VS1, BOX 1981, with minor changes) shown here provides a list of climatically expected plant types and their relative proximities to closest important climatic limit. Some actually occurring possible examples are suggested wherever possible.
Note in particular that:
1) P/PET (annual moisture index) is 0.98, suggesting a lightly closed forest with perhaps persistent openings and a well developed, perhaps persistent understorey.
2) The minimum monthly temperature (15.7C^{o}) is definitely subtropical, suggesting a transition (with overlap) between tropical and temperate plant ranges.
3) Raingreen woody forms are not predicted to occur, since minimum average monthly precipitation is still 39 mm. Tropical raingreen forms would, however, also be near their minimum temperature limits (14-10^{o} in T:VS1) in this subtropical region. Summergreen forms (near limits for required winter cold) are generally predicted instead of the raingreen forms. (The distinction may be rather artificial anyway).

This site illustrates both some strengths and weaknesses of this bioclimatic approach. General form composition is suggested, also with some variations for different substrates/micro-sites. A similar, Northern Hemisphere site might be the area around Tampa (Florida), with mean minimum temperature at 16C^{o} for January, where summergreen trees (e.g. Celtis laevigata) are still important in the natural vegetation but tropical raingreen trees (e.g. Enterolobium) grow well in botanical gardens.

CORRIENTES/Argentina 27.45°S, 58.82°W, 54 m elevation

Temperature (monthly): 27.0° (warmest), 15.7° (coolest)

Precipitation (monthly): 150 mm (most), 39 mm (least), 109 mm (warmest)

Moisture index (annual P/PET): 0.98 (=1231mm/1256mm)

Expected plant forms	distance to limit	Possible examples
T: *Warm-temperate broad-evergreen trees	0.23	Astronium bal., Schinopsis bal. Aspid.qu.-bl.(briefly bare)
Tropical EG sclerophyll trees	0.35	? (probably occur)
Tropical EG microphyll trees	0.23	? (probably occur: EG Acacia? Prosopis?)
*Summergreen broad-leaved trees	0.08	? (many deciduous trees: probably "raingreen")
Not predicted: Raingreen BL trees	--	Enterolobium, Tabebuia ipe, Caesalpinia, Anadenanthera
TT: Palmiform tuft-trees	0.25	Copernicia alba, Butia yatay
ST: Summergreen BL small trees	0.14	? (many deciduous trees: probably "raingreen")
Tropical BL-EG small/dwarf trees	0.08	? (probably occur)
Palmiform tuft-treelets	0.28	Butia yatay
Not predicted: Raingreen BL small trees	--	Prosopis, Acacia
A: Summergreen arborescents	0.31	Salix humboldtiana (this area?)
Evergreen arborescents	0.38	?
Not predicted: Raingreen thorn-scrub	--	understorey Leguminosae (Acacia, Prosopis), Ziziphus
S: Tropical/temperate BL-EG shrubs	0.22	Brunfelsia, Scutia buxifolia, Maytenus ilicifolia
Summergreen BL mesic shrubs	0.19	? (probably more "raingreen")
RS: Palmiform mesic "rosette-shrubs"	0.08	? (trunkless palms?)
Xeromorphic "rosette-shrubs"	0.23	Bromelia serra, Pseudananas macrodontes, Aechmea
SS: Bush stem-succulents	0.45	Opuntia (schultzii?)
G: Tall typical and cane grasses	0.29	Eragrostis, Aristida jubata?, Elyonurus muticus
Arborescent grasses	0.15	? (bamboo: in colonies only, if at all)
Short bunch and sward grasses	0.28	Paspalum?, Melica?
F: Raingreen forbs	0.32	(probably many)
Tropical and temperate EG forbs	0.08	?
Succulent forbs	0.23	?
V: Evergreen vines	0.08	Smilax campestris
E: Wintergreen "epiphytes"	0.21	Phoradendron, Phrygillanthus (this area?)
Not predicted: other epiphytes	--	Rhipsalis, other Cactaceae, Aechmea
hemi-epiphytes	--	Ficus spp.
Th: Mat-forming thallophytes	0.10	mosses, etc.
Xeric thallophytes	0.45	mainly lichens
Only on wetter micro-sites:		
V: Summergreen vines	0.03	? (perhaps "raingreen")
E: Narrow-leaved epiphytes	0.03	Tillandsia spp.
Only on drier micro-sites:		
A: Xeric evergreen tuft-treelets	0.03	Trithrinax campestris (but reportedly does not occur)
Not occurring in Argentina (but climatically possible):		
T: Tropical xeric needle-trees	0.20	(e.g. Widdringtonia, from Africa)
ST: Dwarf-needle small trees	0.25	(e.g. Juniperus, from Northern Hemisphere)
S: Mediterranean evergreen shrubs	0.15	occur in Chile

Expected vegetation formation: Subtropical, mainly evergreen forest with often light canopy closure, perhaps persistent openings, and well developed, form-rich understoreys; tuft and rosette forms important in more open areas.

Actual vegetation: Eastern (mesic), partly evergreen chaco forest, typically with Schinopsis balansae and Astronium balansae plus deciduous Leguminosae in canopy; well developed understoreys, with deciduous scrub, palms, large ground bromeliads, and some cacti especially important (especially on degraded sites); numerous epiphytes, mainly bromeliads and cacti.

Sandy low uplands: Palm savannas (palmares) of Butia yatay and Elyonurus muticus

Many grazed pasture communities, especially with Elyonurus muticus

References: ESKUCHE (1983), CABRERA (1971), RAGONESE and CASTIGLIONE (1970), HUECK (1966), and personal observation

and does not need repetition. The T:VS1 model was not an attempt to "predict" vegetation types or boundaries but rather to suggest potential growth-form composition of vegetation and how this varies geographically. Of course, landscape heterogeneity (e.g. varying topography, different substrates) permits considerable variation in the plant and community types which may occur, even at an individual site. Climatic models can only suggest the inventory of forms which may occur, in some combination or another, in different "patches" in the landscape.
In order to test the "higher-PET" basis for vegetation-climate studies in Argentina and elsewhere, T:VS1 was used (with higher-PET) to generate climatically expectable plant-type lists for the 150 climatic sites used to produce Figure 1. This and initial estimation of the corresponding, actually occurring vegetation were done before coming to Argentina; field verification of actual vegetation was done during the Excursion and afterward (on Tierra del Fuego). As an example of this approach and its results, the climatically expected plant types around Corrientes (city), with some indications of actually occurring taxa, are shown in Table 2. Such results can sometimes provide a useful framework for more intensive vegetation study. This bioclimatic approach works best in large areas with considerable climatic variation, like Argentina, where closed forest does not dominate everywhere and more different growth forms can co-exist in more open vegetation stands.

6. VEGETATION-CLIMATE OBSERVATIONS in ARGENTINA

Several quite good descriptions of the vegetation of all of Argentina have been available for some time (e.g. CASTELLANOS and PEREZ MOREAU 8145, CABRERA 1971, LASSALLE 1980). These are supplemented by detailed maps (e.g. PAPADAKIS 1952, HUECK and SEIBERT 1972, UNESCO 1981) and by descriptions of Argentine vegetation in relation to that of the rest of South America (e.g. HAUMAN 1931, HUECK 1966, TROLL 1968, WEBER 1969). Quite detailed vegetation studies are also available for some regions (e.g. CABRERA 1958, 1968-1970, MARLANGE 1973, LEWIS et al. 1974-1980, LUTI et al. 1979, ROIG and FAGGI 1985). All in all, the general features of Argentine vegetation are quite well known.

Of the 150 T:VS1 profiles generated for Argentina (and some adjacent areas), 25 sites were chosen to represent the main vegetation regions, including some sites observed during the Excursion. The T:VS1 results were also interpreted as climatically expected vegetation formation types and are compared in Table 3 with the actual or hypothesized natural vegetation of these sites. Walter climate types (see WALTER and

Table 3. Climatically expected versus actual (natural) vegetation at representative sites throughout Argentina
Tab. 3. Klimatisch erwartete sowie aktuelle (natürliche) Vegetation repräsentativer Orte Argentiniens
Tab. 3. La vegetación climáticamente esperada versus la vegetación actual (natural) de localidades representativas en la Argentina.

The climatically expected vegetation "predictions" are from model T:VS1, modified very slightly for Tierra del Fuego (BOX 1981). Sites at which the expected vegetation essentially matches the actual (natural) vegetation are indicated by an asterisk preceding the "predicted vegetation". Actual vegetation was determined from various sources (see main text), including personal observations (indicated by an asterisk preceding the "actual vegetation"). The climate types are from WALTER and LIETH (1960-1967) plus the following sub-types:
m = maritime sub-type (i.e. greatly reduced temperature extremes, even in dry climates)
a = arid sub-type (temperate arid climate, but with much reduced continentality in Argentina)
Other abbreviations are as follow:
BL = broad-leaved, EG = evergreen, NL = narrow/needle leaved,
RG = raingreen, SG = summergreen
Note that for Cerro Fitzroy the lack of boreal conifers in South America was considered in evaluating the T:VS1 results. Note also that although the pampa results are reasonable, they cannot be accepted as correct "predictions" since dominance by tussock-grasses is not suggested in the results.

Location	Latitude	Elevation	Walter climate	MI (P/PET)	Predicted vegetation	Actual(natural) vegetation	Important taxa
Northeastern forests							
1. Foz do Iguazú (Brazil)	25.5	162	V	1.40	*form-rich subtrop rainforest (EG) with seasonal and temperate elts.	*form-rich mesic subtropical mainly EG forest	Parapiptadenia, Meliaceae, Lauraceae, Chusquea ramosissima
2. Posadas	27.4	138	V	1.25	*form-rich mesic subtropical mainly EG forest	*subtropical semi-EG mesic forest	Astronium (EG), Tabebuia ipe (RG), Gleditsia, etc.
Chaco							
1. Corrientes	27.5	54	V-II	0.98	*subtropical mainly EG forest with div. understorey	*mesic semi-EG chaco forest; palmares	Astronium, Schinopsis, Prosopis, Butia, Bromelia serra
2. Pres. Roque Saenz Peña	26.8	90	II	0.73	*semi-EG woodland with EG emergents and div. understorey	*semi-EG dry chaco forest (quebracho type)	Aspidosperma, Schinopsis, Prosopis, Stetsonia, Opuntia

Table 3 (continued - Forts.)

Location	Latitude	Elevation	Walter climate	MI (P/PET)	Predicted vegetation	Actual(natural) vegetation	Important taxa
Andes (except south)							
1. Salta	24.8	1178	II	0.66	*dry semi-EG scrub	*dry semi-EG chaco woodland	Prosopis, Acacia, Aspidosperma, Stetsonia, Opuntia
2. Cafayate (dry Andine valley near Salta)	26.0	1700	X(III)	0.14	*mixed semi-desert scrub with succulents	*mixed semi-desert scrub,with succ.; floodplain algarrobo forests	Prosopis, Acacia, Trichocereus, Opuntia, cushion-bromeliads; (?)
3. La Quiaca (Jujuy)	23.1	3458	X(II-III)	0.52	*xeric semi-EG shrub-steppe	dry dwarf-shrub puna	Prosopis,Atriplex shrub Compositae, Verbena, Adesmia, Stipa
4. Villa Nougues (Tucuman)	27.0	1388	X(II)	1.75	*subtropical montane mixed forest with temperate elts.	Tucuman semi-EG montane forests with temperate elts.	Alnus, Juglans, Eugenia, Podocarpus, etc.
5. Uspallata (Mendoza)	32.6	1845	X(II-III)	0.25	*xeric shrub and bunch-grass steppe	*bunch-grass puna with dwarf-shrubs	Stipa, Verbena uniflora, Tephrocactus, Ephedra, Chuquiraga
Central transition							
1. Cordoba	31.4	423	II-VII	0.70	*seasonal short grassland with trees and shrubs	*savanna/woodland: pampa-chaco-espinal transition	Prosopis, Celtis, Trithrinax, Geoffrea, Baccharis
Pampas							
1. Buenos Aires	34.6	25	V-VII	1.01	warm-temperate EG forest with open mosaics	tall-tussock pampa, with forest islands; gallery forest	Stipa, Festuca, Sorghastrum, Sporobolus, etc.
2. General Villegas	35.0	117	VII-V	0.80	diverse grassland with shrubs/arb.	tall-tussock pampa	Stipa, Festuca, Sorghastrum, etc.
3. Bahia Blanca	38.7	24	VIIm	0.59	short-grass and xeric-shrub steppe	drier pampa, near dry scrub	Stipa, Sorghastrum Prosopis
Monte							
1. Mendoza	32.9	755	III-VIIa	0.20	*semi-desert scrub with succulents	*monte shrub-steppe	Larrea, Bulnesia, Prosopis, Trichocereus
2. Malargüe	35.5	1418	X(VIIa)	0.33	*seasonal montane xeric shrubland	monte/montane shrub transition	Larrea, Prosopis
3. Puerto Madryn	42.8	14	(VIIa)m	0.21	*semi-desert shrub-steppe	coastal "monte"	Larrea, Prosopis
Southern Andes							
1. S.C. de Bariloche	41.1	853	X(IV)	1.85	temperate NL-EG rainforest	*submontane dry conifer/SG forest transition	Austrocedrus chilensis, Nothofagus pumilio, N. antarctica
2. Isla Victoria (L. Nahuel Huapi)	41.0	850	X(IV)	3.19	temperate NL rainforest with semi-EG understorey	species-rich mainly BL-EG temperate rainforest	Nothofagus (EG and SG), Lomatia, Drimys, Myrceugenellia
3. Cerro Fitzroy	49.3	358	VIIIm	1.35	*SG forest with semi-EG mixed understorey	BL summergreen notophyll forest	Nothofagus pumilio N. antarctica, Berberis, Maytenus
Patagonia							
1. Maquinchao	41.2	888	(VIIa)m	0.23	*semi-desert shrub-steppe (seasonal)	(*)Patagonian semi-desert shrub-steppe near "monte"	Mulinum spinosum, Stipa, Nassauvia, Verbena, Azorella
2. Sarmiento	45.6	270	(VIIa)m	0.21	*semi-desert shrub-steppe	Patagonian semi-desert shrub-steppe	Mulinum, Stipa, Nassauvia, Verbena
3. Rio Gallegos	51.7	22	(VIIa-IX)m	0.48	*bunch-grass steppe with xeric shrubs	*Patagonian coastal steppe/semi-desert	Stipa, Festuca
Tierra del Fuego							
1. Rio Grande	53.8	9	(IX-VIIa)m	0.84	*cool-temperate grassland with dwarf-shrubs	*Patagonian steppe	Festuca, Hordeum, Empetrum
2. Ushuaia	54.8	7	(IX-VI)m	1.13	*short semi-EG BL forest	*mainly summergreen forest with more EG understorey	Nothofagus pumilio N. betuloides(EG), Berberis
3. Isla de los Estados	54.7	53	IXm	1.16	*semi-evergreen shrub-grass tundra	subantarctic maritime "tundra"	Gramineae, Cyperaceae, Ericaceae, Azorella

LIETH 1960-1967) are included in Table 3 in order to emphasize the unusual nature of some Argentine climates, especially in the south. T:VS1 profiles for 12 of the 25 sites from Table 3 are shown in Appendix A. The 90 "ecophysiognomic" plant types in T:VS1 are described in detail by BOX (1981) and to a very limited extent in Appendix A. The descriptions of actual vegetation are based on personal observation, on materials obtained during the Excursion (ESKUCHE 1983), on the map by HUECK and SEIBERT (1972), and on descriptions by CABRERA (1958, 1971, 1978), HUECK (1966), ROIG (1972), LEWIS et al. (1974-1980), RUTHSATZ (1974), FERNANDEZ (1976), LUTI et al. (1979), VEBLEN et al. (1980), LEON and ANDERSON (1983), SORIANO et al. (1983) and ROIG and FAGGI (1985).

Interpretation of T:VS1 results as a potential vegetation type involves consideration of potential vegetation cover (based on the annual moisture index), the relative height and spread of potentially dominant growth forms, and proximity to closest climatic limit (see (BOX 1981, 1986). Generally speaking, closed forests can occur at or above MI=1.0, more open forests or woodlands at MI = 0.8 to 1.0, and deserts or semi-deserts at MI below 0.3. Between 0.3 and 0.8 (and above) one can find woodlands, grasslands, shrublands, savannas, scrub, or other open vegetation structures, depending mainly on climatic seasonality and local substrate. Below 0.5, scrub vegetation generally has no tall trees (except at wetter microsites) and a more discontinuous ground cover.

In looking at Table 3 and the more detailed results (Appendix A), one can make the following general observations. Most of the 90 plant-type candidates appear to occur somewhere in the unusual diversity of Argentine climates. Some forms, however, appear not to occur naturally at all in South America: boreal/montane short-needled trees (e.g. Picea, Abies), hydric summergreen needle-trees (e.g. Taxodium), typical xeric needle-trees (e.g. Widdringtonia and others, mainly from Africa), dwarf-needle small trees (e.g. Juniperus), and tropical temperate needle-trees (e.g. Pinus sylvestris, P. strobus). Mediterranean evergreen shrubs (e.g. Escallonia, Colliguaja) occur in Chile but do not come far into Argentina. This results in possible "open niches" and a consequent "overprediction" of form richness in the vegetation, perhaps with implications for dominant vegetation physiognomy. This result can be expected in relatively isolated land areas, perhaps especially in transitional, subtropical climates (e.g. also Australia and southern Africa), which have never evolved or been invaded by such "missing" forms.

Some important Argentine taxa, on the other hand, could not be classified. Some such taxa may represent forms not foreseen in T:VS1 (e.g. Diostea juncea, some Chusquea spp.). More frequently, though, taxa could not be classified due to insufficient information of the necessary type, especially seasonality patterns.
The potential form richness of the vegetation actually makes itself seen in more open, degraded, or successional vegetation, where a single form (such as canopy trees) does not dominate. This can be seen especially in degraded chaco woodlands (with arborescents, tall succulents, etc.) and degraded pampa sites (with invasion by shrubs, semi-shrubs, and small trees). Of course form richness may be enhanced even more or effectively reduced on particular substrates (e.g. floodplain Prosopis - Atriplex forests in dry pre-Andine valleys, or simplified Butia yatay palm savannas sandhill sites near Corrientes).
In summary, the poorest match between climatically suggested and actual vegetation appears to occur in the southern Andes (due to the absence of boreal conifers) and to a lesser extent in some pampa areas. At Bariloche (see Appendix A), the natural vegetation was a narrow strip of Austrocedrus forest, with the climatically expected "temperate rainforest needle-trees" occuring a bit further west and south, in the Valdivian rainforest. In the Pampa, grasses gain dominance over other climatically possible forms (which do occur in successional and degraded vegetation) due to various, fairly well understood factors briefly discussed below. The climatic model, however, does not represent the importance of tussock-grasses very well.

7. PARTICULAR REGIONS

It is not possible to discuss sites individually, but perhaps a few regional observations can be summarized:

The puna, often described as mainly a tussock-grassland (e.g. WALTER 1973), also may take the form of a dry shrub-steppe dominated by various needle or scale-leaved evergreen shrubs (e.g. "tola vaca", "tola lejía", "tola" = shrub), "hard" cushion-shrubs (Azorella spp.), and other xeric, Ephedra-like (i.e. leafless) or deciduous dwarf-shrubs, especially above Salta and northward into Jujuy (see Appendix A: La Quiaca; see also CABRERA 1958, 1968, 1978, RUTHSATZ 1974).

The Córdoba area represents an especially interesting transition between the pampa, chaco, "monte" scrub (e.g. Larrea), and "espinal" (Prosopis, Acacia, etc.) vegetation regions, complete with mountains and edaphic anomalies (e.g. salares). All have been well described by LUTI et al. (1979) and by CABRERA (1971) and LEON and ANDERSON (1983). Many plant types appear to approach climatic limits in this area (see also Córdoba results in Appendix A).

Climatically suggested shrubs and other woody plant types can occur in the pampa on degraded or successional sites (e.g. LEON and ANDERSON 1983, FRANGI 1975, LEWIS et al. 1974-1980, CABRERA 1971). Dominance by grasses on more "natural" sites is perhaps the result of dense root networks, sometimes substrate conditions, and the summer dryness, which make it difficult for shrub and tree seedlings to become established in the relatively exposed areas between grass tussocks (see Buenos Aires and Bahia Blanca in Appendix A).

Both the Larrea-dominated "monte" scrub and the montane matorral shrublands (with Adesmia, etc.) near Mendoza are remarkably similar to corresponding vegetations in the western USA, in form composition, in some shared taxa (especially Larrea and Cactaceae), and in their climatic and substrate relationships (cf. BARBOUR and DIAZ 1973).

Both shrub-dominated (e.g. Maquinchao) and grassier (e.g. Rio Gallegos, Rio Grande) Patagonian steppes were well described by T:VS1, but some unusual forms also occur, such as Nassauvia, Anarthrophyllum, etc. (see also HAUMANN 1926, CABRERA 1971, 1978, SORIANO 1956, SORIANO et al. 1983).

The nemoral (e.g. Bariloche) and summergreen subpolar (e.g. Ushuaia) Nothofagus forests/scrub and their climatic relationships correspond well to Betula and other summergreen forests/scrub in similar maritime high-latitude situations of the Northern Hemisphere. Subpolar evergreen N. betuloides, however, may be unique in high latitudes and suggests the cool but long, humid growing seasons of equatorial subalpine forests (e.g. Polylepis in Venezuela, Erica arborea and Philippia excelsa of eastern Africa; see also TROLL and LAUER 1978).

8. SPECIAL PLANT TYPES

It also is not possible here to discuss individual plant types in detail, but perhaps some observations can be summarized briefly:

Many types of needle-leaved trees are completely missing from the flora of South America, but such species from other continents often do well when introduced into the appropriate environments (e.g. Casuarina cunninghamiana, Pinus spp.). The climatically suggested niches for these missing needle-trees seem to be filled in the native vegetation by Nothofagus spp. in more maritime areas (cf. Betula in similar Northern Hemisphere areas) and perhaps by micro-sclerophyll evergreens in the subtropics (e.g. Aspidosperma quebracho-blanco, with small, pointed sclerophylls, as the closest equivalent near Corrientes to a "tropical xeric needle- tree").

The distinction between "summergreen" and "raingreen" deciduous woody forms may have some basis (degree of bud protection, geographic origin/ affinity, etc. see RUEBEL 1930) but may also be somewhat artificial, as seen by the suggestion of summergreen rather than raingreen forms at Corrientes (Table 2).
Tall stem-succulents are important in perhaps unexpectedly humid climates (e.g. chaco forests), especially in degraded stands and on special substrates (see ESSER 1982). Macroclimatic niches of stem-succulents and puna dwarf-shrubs seem to overlap considerably on dry Andes slopes below 3500 m, but mixed stands were difficult to find.
Xeric dwarf and cushion-shrubs (see RAUH 1939, cf. WALTER and BOX 1983 for Eurasia) are especially important in two areas: the puna (CABRERA 1958, 1968, RUTHSATZ 1974) and the Patagonian steppe/semi-desert (CABRERA 1978, SORIANO et al. 1983). More mesomorphic cushion-shrubs (especially Azorella) are important on windy, ultra-maritime subantarctic islands.
Xeric, often at least partly leaf-succulent rosette forms, mostly bromeliads, are unusually important in a variety of situations over much of Argentina (e.g. as epiphytes, in chaco unterstoreys, on rocky substrates of dry Pre-Andine valleys). Tougher forms seem to be favored by grazing.
Bamboo taxa are important as climbers (Chusquea ramossissima) in humid subtropical forests and as understorey invaders (Ch. culeou, erect to 1-2 m) in degraded, cool-temperate Nothofagus forests (cf. Sasa in cool-mesic forests of Japan).
Leafless or nearly leafless stemgreen arborescents and shrubs are especially important in two areas. Diostea juncea (Verbenaceae, to 7 m) is an important, seemingly unusual invader of degraded cool-temperate forests, while similar leafless shrubs (e.g. Discaria, some Cassia spp., other Verbenaceae) are common in dry environments.

Finally one must say a bit more about the Fuegan Nothofagus species, which occur as erect trees forming closed forests at lower summer maximum temperatures (but with long growing seasons and perhaps higher temperature sums) than any other temperate-zone trees in the world. Especially interesting are the evergreen N. betuloides forests, unique in the subpolar zones. Upon visiting Ushuaia (55°S; see also Appendix A) in early November 1983, I found the new leaves of summergreen N. pumilio and N. antarctica apparently fully developed (despite intermittent snowfall), far ahead of these same species at Bariloche (41°S) only a few days earlier. This underscores the long growing season of the ultra-maritime Fuegan climate.
To some extent, the importance of particular growth forms must be due to the radiative speciation of established genera and families. The relatively good correspondence to particular climatic or microclimatic situations, however, suggests that history is not the whole story. The ecology of particular growth forms, less common in other parts of the world, should be studied as such in Argentina.

SUMMARY

Many vegetation-climate models have not worked well in Argentina, due mainly to poor estimation of potential evapotranspiration (PET) and the overall water balance. In this study, several estimators of PET are compared in humid-dry transitional regions in order to determine which PET estimator works best throughout Argentina while also permitting comparison of Argentine vegetation-climate relationships with those in other parts of the world. Taking always the higher of the Thornthwaite versus Holdridge PET estimates, at the particular site, seems to represent an improvement which will permit consistent bioclimatic work. Using this PET basis with an existing world model of plant growth forms, climatically expectable plant-form compositions of vegetation were generated for 150 sites throughout Argentina. Except for plant types which do not occur at all in Argentina (or in South America), and despite some unusual climatic situations, these vegetation "predictions" seem mostly reasonable, suggesting that Argentine plant-climate relationships are in line with those elsewhere. A few unusual plant types and situations were also suggested, which contribute to the particular character of Argentine vegetation.

ZUSAMMENFASSUNG

Viele klimatische Vegetationsmodelle sind wegen schlechter Schätzung der potentiellen Evapotranspiration (PET) und dabei der gesamten Wasserbilanz in Argentinien gescheitert. In dieser Arbeit werden einige PET-Schätzungsmethoden in feucht-trockenen Uebergangszonen verglichen, um die für Argentinien sowie für weltweite bioklimatische Vergleiche beste PET-Basis zu finden. Die jeweils grössere der Schätzungen nach Thornthwaite bzw. Holdridge scheint eine verbesserte, zuverlässige PET-Basis für bioklimatische Arbeit zu liefern. Diese PET-Basis wurde mit einem Modell der klimatischen Verhältnisse verschiedener Wuchsformen verwendet, um die klimatisch zu erwartende Formen-Zusammensetzung der Vegetation an 150 Punkten in Argentinien zu bestimmen. Von einigen in Argentinien bzw. in Südamerika überhaupt nicht vorkommenden Formen abgesehen, und trotz einiger ungewöhnlicher Klimate, erscheinen diese "Voraussagen" meistens vernünftig. Argentinische phytoklimatische Verhältnisse würden also mit globalen Verhältnissen gut übereinstimmen. Einige besonders interessante Pflanzentypen sowie Situationen wurden auch angedeutet, die zum besonderen Charakter argentinischer Vegetation beitragen.

RESUMEN

Muchos modelos fitoclimáticos no han funcionado bién en Argentina debido a la mala estimación de la evapotranspiración potencial (ETP) y del balance total de agua. En este estudio se comparan varias estimaciones de la ETP en regiones climáticamente transicionales para identificar cual índice de la ETP da valores más realistas para Argentina que también permitan comparaciónes fitoclimáticas con otras partes del mundo. Tomar siempre la estimación mayor de ETP, calculada por los métodos de Thornthwaite y Holdridge, parece mejorar la base evapotranspiracional para trabajos bioclimáticos. Sobre esta base, un modelo fitoclimático mundial de biotipos fue utilizado para determinar la composición de la vegetación que de acuerdo al clima debería encontrarse en 150 sitios a través

de Argentina. Con excepción de algunas formas que no existen en Argentina (o en Suramérica), las "predicciones" vegetales parecen razonables. Este resultado sugiere que las relaciones fitoclimáticos en Argentina corresponden bastante bién con los patrones fítoclimáticos globales, no obstante el carácter insólito de algunos climas argentinos. Se sugieren también algunos biotipos y situaciones vegetales peculiares que contribuyen al carácter particular de la vegetación de Argentina.

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APPENDIX A: Climatically expected vegetation compositions at selected sites in Argentina

ANHANG A: Klimatisch erwartete Zusammensetzungen der Vegetation ausgewählter Orte Argentiniens

ANEXO A: La composición climáticamente esperanda de localidades seleccionadas de la Argentina

The climatically expected vegetation composition, in terms of plant growth forms ("life forms"), is generated by the model T:VS1 (BOX 1981, see also main text), based on wordlwide bioclimatic relationships. Each vegetation profile generated consists of a list of plant types whose empirically determined climatic tolerance limits would appear to permit them to occur at the particular site. Seven monthly or annual temperature and precipitation variables are employed in the model, plus an annual moisture index (MI, = precipitation divided by potential evapotranspiration, (PET) based on the "maximum PET" value described in the main text. Some climatic limits have been modified slightly for South America, but all changes were checked against world patterns before being accepted.
Each profile shows the site name and location, the climatic data used, the expected plant forms and a standardized measure of relative "distance" (zero to one) to the closest important climatic limit. These distances can be interpreted as indications of potential importance ("fitness") of the respective plant forms, especially if a form is occuring quite near a climatic limit. Apparent requirements of wetter, drier, or more protected (warmer) micro-sites are listed separately.
The plant types are arranged in the profiles by growth form, generally from larger to smaller, based on the following classes:
T = trees (normal stature)
ST = small trees and treelets (short canopy or understorey forms)
TT = tuft-trees and treelets (e.g. palms, tree ferns)
A = arborescents (less well-defined tree or "overgrown bush" forms, often phreatophytic)
S = shrubs (including dwarf-shrubs)
CS = cushion-shrubs
RS = "rosette-shrubs" (e.g. ground bromeliads, trunkless palms)
SS = stem-succulents (including arborescent and/or Lignifying bush forms)
G = graminoids (mainly grasses)
F = forbs (herbs except graminoids and ferns)
H = undifferentiated small herbs (forbs and graminoids) of stressed, usually highly seasonal environments; plants generally short- lived
Fn = ferns (excluding tree ferns and epiphytes)
V = vines and lianas
E = epiphytes (including epiphytic ferns, succulents, graminoids and semi-parasitic "epiphytes")
Th = "thallophytes" (including mosses, liverworts, algae and lichens).

All plant forms are defined structurally and explained with examples in BOX (1981). A prepared appendix of possible examples in Argentina was detected as too long to being included here.
At the bottom of each profile is an interpretation of the results as an expected vegetation formation. This interpretation is based on the annual moisture index (an estimate of total vegetative cover and potential dominant structural types), the relative size and spread of the growth forms predicted and the proximity of forms to climatic limits. (A more

complete description of the results and their interpretation was given recently by BOX 1986). Plant forms selected by computer algorithm as the most likely dominant or co-dominant forms are indicated by an asterisk (*) in closed stands (MI above 0.9) or by a plus (+) in open stands. Forms not occurring at all in Argentina or South America, mainly conifer types, are listed separately.
For comparison, a description of the vegetation actually occurring at the site is also included. These brief description are based on personal observation where possible (indicated by an asterisk), on descriptions in the literature, and, where possible, on descriptions of species compositions and seasonality patterns obtained during the Excursion in Argentina.

BAHIA BLANCA (Pampa)/Argentina 38.72°S, 62.25°W, 25 m elevation
Temperature (monthly): 23.6°C (warmest), 8.0°C (coldest)
Precipitation (monthly): 67 mm (most), 22 mm (least), 50 mm (warmest)
Moisture index (annual P/PET): 0.59 (= 539 mm/914 mm)

Expected plant forms:		distance to limit
A:	Summergreen arborescents	0.32
	Leafless/leptophyll arborescents	0.34
S:	+Xeric summergreen shrubs	0.46
	Narrow/needle-leaved evergreen shrubs	0.32
	Xeric dwarf-shrubs	0.37
	Xeric cushion-shrubs	0.43
RS:	Xeric "rosette-shrubs"	0.18
SS:	Bush stem-succulents	0.27
G:	Short dwarf-grasses	0.15
	+Short bunch-grasses	0.64
	Short tussock-grasses	0.06
F:	Summergreen forbs	0.46
	Succulent forbs	0.12
	Xeric cushion-herbs	0.26
Th:	Xeric thallophytes	0.64
Only on protected, warmer micro-sites:		
T:	(Tropical evergreen sclerophyll trees)	0.00
ST:	(Broad-leaved raingreen small trees)	0.00
TT:	(Xeric evergreen tuft-treelets)	0.00
A:	(Evergreen arborescents)	0.00
F:	Raingreen forbs	0.04
Geographically unlikely but climatically possible:		
ST:	Dwarf-needle small trees	0.24
S:	Mediterranean evergreen shrubs	0.23

Expected vegetation formation: Short grass and xeric-shrub steppe, with arborescents and more shrub forms in ravines or on degraded/more protected sites.
Actual vegetation: Dry pampas grassland (steppe) near transition to dry scrub (near chaco-monte transition belt).

San Carlos de BARILOCHE (Andes)/Argentina 41.15°S, 71.30°W, 853 m elevation

Temperature (monthly): 14.6°C (warmest), 3.2°C (coldest)
Precipitation (monthly): 192 mm (most), 30 mm (least/warmest)
Moisture index (annual P/PET): 1.85 (= 1066 mm/576 mm)

Expected plant forms:		distance to limit
T:	*Temperate rainforest needle-trees	0.15
	Submediterranean needle-trees	0.04
	Summergreen broad-leaved trees	0.00
ST:	Broad-leaved summergreen small trees	0.32
	Temperate broad-evergreen small trees	0.09
A:	Summergreen arborescents	0.32
S:	Broad-leaved summergreen mesic shrubs	0.04
	Needle narrow-leaved evergreen shrubs	0.09
	Maritime heath dwarf-shrubs	0.24
	Temperate evergreen dwarf-shrubs	0.15
G:	Tall cane-grasses	0.08
	Short sward-grasses	0.15
	Short bunch-grasses	0.62
F:	Temperate evergreen forbs	0.32
	Summergreen forbs	0.28
Th:	Mat-forming thallophytes	0.57
	Xeric thallophytes	0.08
Geographically unlikely but climatically possible:		
H:	(Raingreen cold-desert herbs)	0.03

Expected vegetation formation: Sub-mediterranean needle-leaved rainforest, with summergreen trees perhaps in clearings; mainly broad-leaved semi-evergreen understorey

*Actual vegetation: Narrow transition region between sub-mediterranean dry conifer forest (Austrocedrus chilensis) and summergreen Nothofagus forest, with more evergreen understorey

On slopes above Bariloche: Based on climate alone, T:VS1 suggests that full-stature summergreen trees would disappear (too cold in summer) and that boreal/montane needle-trees would soon appear and probably dominate. Since this boreal form does not occur in South America, one might expect instead that a short broad-leaved summergreen forest/woodland would appear upward as it becomes too cold for other needle-trees. In reality this is what happens, except that the summergreen trees (Nothofagus pumilo mainly) are not at all so short, nor are the admixed evergreen N. betuloides. There is also some basis for expecting this: ELTON and MEENTEMEYER (1979) found, for example, that the tallest individuals of summergreen broad-leaved species in the USA tend to grow at the cool end of their ranges.

BUENOS AIRES/Argentina 34.58°S, 58.48°W, 25 m elevation
Temperature (monthly) : 23.1°C (warmest), 9.4°C (coldest)
Precipitation (monthly): 112 mm (most), 57 mm (least), 78 mm (warmest)
Moisture index (annual P/PET): 1.01 (= 957 mm/951 mm)

Expected plant forms:		distance to limit
T:	*Warm-temperate broad-leaved evergreen trees	0.18
	*Summergreen broad-leaved trees	0.11

	Tropical evergreen microphyll trees	0.10
	Tropical evergreen sclerophyll trees	0.06
ST:	Broad-leaved summergreen small trees	0.31
	Temperate broad-leaved evergreen small trees	0.26
	Tropical broad-leaved evergreen small trees	0.07
A:	Summergreen arborescents	0.47
	Evergreen arborescents	0.07
S:	Temperate broad-leaved evergreen shrubs	0.41
	Broad-leaved summergreen mesic shrubs	0.31
	Tropical broad-leaved evergreen shrubs	0.14
	Narrow/neeedle-leaved evergreen shrubs	0.48
	(Temperate evergreen dwarf-shrubs)	0.05
RS:	(Palmiform mesic "rosette-shrubs")	0.06
SS:	Bush stem-succulents	0.31
G:	Tall typical and cane-grasses	0.30
	Short sward-grasses	0.47
	Tall tussock-grasses	0.10
	Short bunch-grasses	0.67
	Short tussock-grasses	0.08
F:	Summergreen forbs	0.48
	Tropical and temperate evergreen forbs	0.11
V:	Evergreen vines	0.11
E:	Wintergreen "epiphytes"	0.34
Th:	Mat-forming thallophytes	0.21
	Xeric thallophytes	0.67
Only in wetter micro-environments:		
V:	Summergreen vines	0.01
E:	Narrow-leaved epiphytes	0.01
Colonial, only in patches:		
G:	Arborescent grasses	0.21
Geographically unlikely but climatically possible:		
T:	Temperate needle-leaved trees	0.10
	Tropical xeric needle-leaved trees	0.07
	(Heliophilic long-needled trees)	0.01
	Sub-mediterranean needle-leaved trees	0.16
ST:	Dwarf-needle small trees	0.42
S:	Mediterranean evergreen shrubs	0.34

Expected vegetation formation: Warm-temperate seasonal forest, perhaps patchy and/or with openings; potentially form-rich understorey

Actual vegetation: Originally tall-tussock pampa with forest islands or coastal strip of actual forest (opinions differ); probably a mosaic of forest and grassland patches.

(Note the large number of needle-leaved tree forms climatically possible, as well as the mediterranean shrubs. Of these, only a juniperoid dwarf-needle small tree would likely be an aggressive invader).

CORDOBA/Argentina 31.42°S, 64.20°W, 423 m elevation
Temperature (monthly): 23.5°C (warmest), 10.0°C (coldest)
Precipitation (monthly): 117 mm (most), 8 mm (least), 106 mm (warmest)
Moisture index (annual P/PET): 0.70 (= 703 mm/1004 mm)

Expected plant forms:		distance to limit
T:	(Tropical evergreen sclerophyll trees)	0.09
ST:	(Broad-leaved raingreen small trees)	0.09

A:	+Summergreen arborescents	0.44
	Raingreen thorn-scrub	0.09
	Evergreen arborescents	0.10
TT:	Xeric evergreen tuft-treelets	0.09
S:	Temperate broad-leaved evergreen shrubs	0.15
	Needle-leaved evergreen shrubs	0.44
CS:	Xeric cushion-shrubs	0.29
RS:	Xeric "rosette-shrubs"	0.17
SS:	(Arborescent stem-suculents)	0.08
	Buch stem-succulents	0.33
G:	+Short sward and bunch grasses	0.40
F:	Summergreen forbs	0.46
	Raingreen forbs	0.13
	Succulent forbs	0.20
	Xeric cushion-herbs	0.26
E:	Wintergreen "epiphytes"	0.15
TH:	Xeric thallophytes	0.65
Only on wetter micro-sites:		
ST:	Broad-leaved summergreen small trees	0.00
S:	Tropical broad-leaved evergreen shrubs	0.00
	Broad-leaved summergreen mesic shrubs	0.00
	Tropical broad-leaved evergreen shrubs	0.14
	Temperate evergreen dwarf-shrubs	0.00
G:	Tall cane and typical grasses	0.00
Only on drier micro-sites:		
S:	Hot-desert evergreen shrubs	0.07
Only on protected, warmer micro-sites:		
T:	Xeric raingreen trees	0.00
TT:	Palmiform tuft-treelets	0.00
V:	Raingreen vines	0.00
Geographically unlikely but climatically possible:		
T:	Temperate needle-leaved trees	0.06
	Tropical xeric needle-leaved trees	0.00
ST:	+Dwarf-needle small trees	0.36
S:	Mediterranean evergreen shrubs	0.19

Expected vegetation formation: Seasonal short grassland with scattered, mainly deciduous arborescents and small trees, plus mainly evergreen scrub forms

*Actual vegetation: Pampa-chaco-monte-espinal transition area, grassy open scrub/savanna mosaic, with Prosopis, Celtis, Geoffreya, Trithrinax, etc.

Note the large number of forms near apparent climatic limits: transition area with potentially high form and species diversity. (Note also that the computer selected "dwarf-needle small tress", a form not occurring in Argentina (e.g. Juniperus in Northern Hemisphere), as a potential dominant; its place is taken perhaps by the summergreen arborescents).

LA QUIACA (Jujuy)/Argentina 22.13°S, 65.60°W, 3458 m elevation
Temperatures (monthly): 12.9°C (warmest), 3.7°C (coldest)
Precipitation (monthly): 88 mm (most), 0 mm (least), 55 mm (warmest)
Annual moisture index (P/PET): 0.52 (=304/585 mm)

Expected plant forms:		distance to limit
S:	+Needle-leaved evergreen shrubs	0.19
	Xeric dwarf-shrubs	0.06
CS:	Xeric cushion-shrubs	0.29
SS:	Bush stem-succulents	0.12
G:	+Short bunch-grasses	0.63
F:	Summergreen forbs	0.19
H:	Xeric cushion-herbs	0.53
	Raingreen cold-desert herbs	0.15
Th:	Xeric thallophytes	1.00

Expected vegetation formation: Xeric semi-evergreen shrub-steppe
Actual vegetation: Dry puna (= bunch-grass and xeric-shrub steppe), probably with Stipa, "tola" shrubs (mostly Compositae, evergreen), and cushion forms.

MAQUINCHAO (Patagonia)/Argentina 41.25°S, 68.73°W, 888 m elevation
Temperatures (monthly): 18.1°C (warmest), 1.2°C (coldest)
Precipitation (monthly): 20 mm (most), 4 mm (least), 8 mm (warmest)
Annual moisture index (P/PET): 0.21 (=126/600 mm)

Expected plant forms:		distance to limit
A:	Leafless/leptophyll arborescents	0.15
S:	+Cold-winter xeromorphic shrubs	0.18
	+Xeric dwarf-shrubs	0.30
CS:	Xeric cushion-shrubs	0.21
SS:	Bush stem-succulents	0.04
G:	+Desert grasses	0.68
H:	Ephemeral desert herbs	0.44
	Xeric cushion-herbs	0.06
Th:	Xeric thallophytes	0.78

Expected vegetation formation: Seasonal semi-desert shrub-steppe
Actual vegetation: Patagonian semi-desert shrub-steppe with Stipa spp., Festuca spp., Mulinum spinosum (CS), Nassauvia spp., etc.

MENDOZA/Argentina 32.88°S, 68.83°W, 755 m elevation
Temperatures (monthly): 23.6°C (warmest), 7,5°C (coldest)
Precipitation (monthly): 27 mm (most), 5 mm (least), 25 mm (warmest)
Annual moisture index (P/PET): 0.20 (=189/945 mm)

Expected plant forms:		distance to limit
A:	+Leafless/leptophyll arborescents	0.34
S:	+Hot-desert evergreen shrubs	0.06
	Xeric dwarf-shrubs	0.45
CS:	Xeric cushion-shrubs	0.42
RS:	Xeric "rosette-shrubs"	0.17
SS:	Bush stem-succulents	0.25

	Typical stem-succulents	0.02
G:	+Desert grasses	0.64
F:	Succulent forbs	0.10
H:	Ephemeral desert herbs	0.57
	Xeric cushion-herbs	0.01
Th:	Xeric thallophytes	0.64

Expected vegetation formation: Mainly evergreen mixed semi-desert scrub, with succulents and cushion forms

*Actual vegetation: "Monte" shrub-steppe and mixed scrub, with Larrea, Bulnesia, Prosopis, etc.

(Note that "hot-desert evergreen shrubs" (e.g. Larrea) are expected co-dominants despite relative proximity to minimum-temperature limits. This is possible in climates where all forms may be under considerable stress. Larrea, relatively large shrubs with relatively large evergreen leaves (compared with the other forms), has the highest potential productivity of the forms listed.)

POSADAS (Misiones)/Argentina 27.40°S, 55.83°W, 138 m elevation
Temperatures (monthly): 26.6°C (warmest), 15.6°C (coldest)
Precipitation (monthly): 176 mm (most), 91 mm (least), 126 mm warmest)
Annual moisture index (P/PET): 1.25 (=1550/1240 mm)

Expected plant forms:		distance to limit
T:	*Warm-temperate broad-evergreen trees	0.34
	*Summergreen broad-leaved trees	0.23
	*Heliophilic long-needled trees	0.20
	*Tropical linear-leaved trees	0.11
	*Temperate broad-leaved rainforest trees	0.09
	Tropical evergreen sclerophyll trees	0.35
	Tropical evergreen microphyll trees	0.32
ST:	Tropical broad-leaved evergreen small trees	0.28
	Broad-leaved summergreen small trees	0.16
TT:	Palmiform tuft-trees	0.24
	Palmiform tuft-treelets	0.28
A:	Summergreen arborescents	0.32
	Evergreen arborescents	0.38
S:	Tropical and temperate broad-evergreen shrubs	0.24
	Broad-leaved summergreen mesic shrubs	0.21
RS:	Palmiform mesic "rosette-shrubs"	0.28
SS:	Bush stem-succulents	0.21
G:	Tall cane and typical grasses	0.34
	Arborescent grasses	0.17
	Short sward-grasses	0.29
	Short bunch-grasses	0.47
F:	Tropical evergreen forbs	0.28
	Temperate evergreen forbs	0.14
Fn:	Evergreen ferns	0.12
V:	Tropical broad-leaved evergreen lianas	0.20
	Broad-leaved evergreen (typical) vines	0.25
E:	Broad-leaved wintergreen "epiphytes"	0.24
	Narrow-leaved epiphytes	0.20
	Tropical broad-leaved evergreen epiphytes	0.12
Th:	Mat-forming thallophytes	0.12
	Xeric thallophytes	0.47

Geographically unlikely but climatically possible:

T:	Hydric summergreen needle-leaved trees	0.20
ST:	Dwarf-needle small trees	0.28

Expected vegetation formation: Form-rich mesic subtropical, mainly evergreen forest with some temperate elements.

*Actual vegetation: Subtropical semi-evergreen mesic forest, with semi-evergreen overstorey (Parapiptadenia, Nectandra, etc.) and almost completely evergreen understoreys (vegetation largely destroyed).

PRES. ROQUE SAENZ PENA (Chaco)/Argentina 26.78°S, 60.47°W, 90 m elevation

Temperature (monthly): 27.9°C (warmest), 16.0°C (coldest)
Precipitation (monthly): 133 mm (most), 25 mm (least), 126 mm (warmest)
Moisture index (annual P/PET): 0.73 (= 942 mm/1290 mm)

Expected plant forms:		distance to limit
T:	+Tropical evergreen sclerophyll trees	0.32
	+Xeric raingreen trees	0.30
ST:	Broad-leaved raingreen small trees	0.36
TT:	Xeric evergreen tuft-treelets	0.36
A:	Summergreen arborescents	0.27
	Evergreen arborescents	0.34
SS:	Bush stem-succulents	0.40
S:	Temperate broad-leaved evergreen shrubs	0.14
	Leaf-succulent evergreen shrubs	0.11
	Xeric cushion-shrubs	0.19
RS:	Xeric "rosette-shrubs"	0.39
G:	Short sward-grasses	0.24
	+Short bunch-grasses	0.40
F:	Raingreen forbs	0.28
	Succulent forbs	0.44
	Xeric cushion-herbs	0.08
V:	Raingreen vines	0.30
E:	Wintergreen "epiphytes"	0.15
Th:	Xeric thallophytes	0.40
Only on wetter micro-sites:		
ST:	Broad-leaved summergreen small trees	0.04
TT:	Palmiform tuft-trees and treelets	0.04
S:	Summergreen mesic and tropical evergreen shrubs	0.04
G:	Tall typical and cane grasses	0.04
Only on drier micro-sites:		
A:	Raingreen thron-scrub	0.10
SS:	Arborescent stem-succulents	0.10
Not in Argentina (but climatically possible):		
T:	Tropical xeric needle-trees	0.07
ST:	Dwarf-needle small trees	0.18

Expected vegetation formation: Semi-evergreen dry, somewhat open/short woodland, with emergent larger trees and diverse understorey, especially in (probably persistent) clearings

Actual vegetation: Semi-evergreen "chaco" woodland, once probably closed but now degraded and more open; now with taller emergent trees (mainly evergreen Aspidosperma quebracho-blanco and Schinopsis quebracho-colorado, plus deciduous Prosopis spp.), plus tall, conspicuous stem-succulents (Stetsonia coryne, Opuntia quimilo) and a dense understorey of mainly deciduous thorn-scrub plus large ground bromeliads.

RIO GRANDE (Tierra del Fuego)/Argentina 53.80°S, 67.78°W, 9 m elevation
Temperatures (monthly): 9.4°C (warmest), -1.1°C (coldest)
Precipitation (monthly): 50 mm (most), 23 mm (least), 40 mm (warmest)
Annual moisture index (P/PET): 0.84 (=410/488 mm)

Expected plant forms:		distance to limit
S:	Summergreen tundra dwarf-shrubs	0.17
	Temperate evergreen dwarf-shrubs	0.17
CS:	Xeric cushion-shrubs	0.07
G:	*Short sward-grasses	0.37
	+Short bunch-grasses	0.65
H:	Seasonal cold-desert herbs	0.49
	Xeric cushion-herbs	0.20
	Raingreen cold-desert herbs	0.15
Th:	Mat-forming thallophytes	0.05
	Xeric thallophytes	1.00

Expected vegetation formation: Seasonal sub-humid grassland with dwarf-shrubs
*Actual vegetation: Pasture and rangeland, originally Patagonian steppe (sub-mesic) with fairly dense cover of primarily _Festuca_ spp.

SALTA/Argentina 24.77°S, 65.47°W, 1178 mm elevation
Temperatures (monthly): 22.2°C (warmest), 11.7°C (coldest)
Precipitation (monthly): 182 mm (most), 1 mm (least), 155 mm (warmest)
Annual moisture index (P/PET): 0.66 (=695/1053 mm)

Expected plant forms:		distance to limit
T:	+Tropical evergreen sclerophyll trees	0.17
	Xeric raingreen trees	0.08
ST:	+Broad-leaved raingreen small trees	0.17
	(Dwarf-needle small trees)	0.29
TT:	Xeric evergreen tuft-treelets	0.17
A:	Summergreen arborescents	0.40
	Raingreen thorn-scrub	0.17
	Evergreen arborescents	0.18
S:	Temperate broad-evergreen shrubs	0.10
	Needle-leaved evergreen shrubs	0.40
RS:	Xeric "rosette-shrubs"	0.11
SS:	Bush stem-succulents	0.39
G:	+Short bunch-grasses	0.71
F:	Summergreen forbs	0.50
	Raingreen forbs	0.20
	Succulent forbs	0.19
H:	Xeric cushion-herbs	0.32
V:	Broad-leaved raingreen vines	0.08
E:	Broad-leaved wintergreen "epiphytes"	0.10
Th:	Xeric thallophytes	0.74
Mainly on warmer micro-sites:		
SS:	Arborescent stem-succulents	0.01

Geographically unlikely but climatically possible:
ST: Dwarf-needle small trees 0.29
Expected vegetation formation: Dry semi-evergreen scrub with scattered trees and some succulents
*Actual vegetation: Dry semi-evergreen chaco woodland, perhaps originally somewhat dense but easily degraded and remaining more open. Main taxa include Prosopis, Acacia, and the "quebracho" species (Aspidosperma, Schinopsis), with arborescent Stetsonia and Opuntia.

USHUAIA (Tierra del Fuego)/Argentina 54.82°S, 68.32°W, 7 m elevation
Temperatures (monthly): 9.5°C (warmest), 0.9°C (coldest)
Precipitation (monthly): 70 mm (most), 33 mm (least), 50 mm (warmest)
Annual moisture index (P/PET): 1.13 (=592/524 mm)

Expected plant forms:		distance to limit
ST:	Broad-leaved summergreen small trees	0.04
	Subpolar broad-evergreen small trees	0.02
A:	Summergreen arborescents	0.04
S:	Summergreen tundra dwarf-shrubs	0.30
	Temperate evergreen dwarf-shrubs	0.30
G:	Short sward-grasses	0.39
	Tall tussock-grasses	0.17
	Short bunch-grasses	0.65
	Short tussock-grasses	0.11
F:	Temperate evergreen forbs	0.20
H:	Seasonal cold-desert herbs	0.48
Th:	Mat-forming thallophytes	0.29
	Xeric thallophytes	0.78

Expected vegetation formation: Stressed, perhaps somewhat short semi-evergreen broad-leaved forest/woodland with well developed understorey
*Actual vegetation: Generally dense, mainly summergreen Nothofagus forest with well developed, more evergreen understorey (N. pumilio, Berberis spp., also N. betuloides, N. antarctica)
(Some climatic limits for the small-tree forms were modified slightly from the original T:VS1 model.)

APPENDIX B: Estimates on the annual moisture index at sites in the humid-dry transition regions of Argentina

ANHANG B: Schätzungen der jährlichen Wasserbilanz in den feuchten/ trockenen Uebergangszonen Argentiniens

The annual moisture index (MI) is defined as annual precipitation divided by annual potential evapotranspiration (PET). Annual MI was computed using four different estimates of PET: Holdridge and Thornthwaite PET formulas, their average, and the higher of their two values at the particular site. The precipitation data are from WILLMOTT et al. (1981). Of the four methods employed, the moisture index based on the higher PET value ("maximum PET") appears to correspond best with actual and hypothesized natural vegetation patterns in these transitional regions of Argentina, as well as on other continents.

			Annual moisture indices			
Location	Latitude	Precipitation	Thornthwaite	Holdridge	Thorn.-Hold. Higher PET	Thorn.-Hold. Average
Northeastern Region						
Villarica (Paraguay)	25.7	1444	1.31	1.11	1.11	1.21
Loreto	27.4	1353	1.38	1.12	1.12	1.25
Posadas	27.4	1550	1.49	1.25	1.25	1.37
Mercedes	29.2	1219	1.21	1.01	1.01	1.11
Paso de los Libres	29.7	1296	1.32	1.10	1.10	1.21
La Paz	30.7	1034	1.10	0.91	0.91	1.00
Eastern Chaco						
Formosa	26.2	1219	1.10	0.94	0.94	1.02
Corrientes	27.5	1231	1.15	0.98	0.98	1.06
Pres. Roque Saenz Pena	26.8	942	0.85	0.73	0.73	0.79
Pampa (eastern)						
Buenos Aires	34.6	957	1.22	1.01	1.01	1.11
Las Flores	36.0	922	1.20	1.02	1.02	1.11
Dolores	36.3	912	1.23	1.04	1.04	1.14
Mar del Plata	38.0	729	1.06	0.92	0.92	0.99
Pampa (central)						
Chivilcoy	34.9	917	1.16	0.96	0.96	1.06
Junin	34.6	904	1.13	0.94	0.94	1.04
Azul	36.8	831	1.17	1.02	1.02	1.10
Tres Arroyos	38.4	695	0.96	0.84	0.84	0.90
Pampa (western)						
Laboulaye	34.1	762	0.92	0.76	0.76	0.84
Gen. Villegas	35.0	770	0.95	0.80	0.80	0.87
Trenque Lauquen	36.0	770	0.97	0.82	0.82	0.89
Guamini	37.0	661	0.84	0.72	0.72	0.78
Cordoba region						
Cordoba	31.4	703	0.86	0.70	0.70	0.78
Rio Cuarto	33.1	780	0.98	0.82	0.82	0.90
Andes (northern)						
S.S. de Jujuy (1303 m)	24.2	810	1.01	0.79	0.79	0.90
Salta (1178 m)	24.8	695	0.84	0.66	0.66	0.75
Villa Nougues (1388 m)	26.9	883	1.27	1.06	1.06	1.16
S.M. de Tucuman (447 m)	26.8	959	1.06	0.86	0.86	0.96
Andes (southern)						
S.C. de Bariloche (853 m)	41.1	1066	1.85	2.10	1.85	1.97
Esquel (568 m)	42.9	473	0.80	0.90	0.80	0.85
Paso del Aguila (900 m)	47.8	302	0.65	1.23	0.65	0.94
Tierra del Fuego						
Rio Gallegos	51.7	264	0.48	0.66	0.48	0.57
Cabo Virgines	52.4	282	0.52	0.76	0.52	0.64
Punta Arenas (Chile)	53.2	426	0.77	1.09	0.77	0.93
Rio Grande	53.8	410	0.84	1.59	0.84	1.22
Ushuaia	54.8	592	1.13	1.86	1.13	1.49
Bahia Douglas (Chile)	55.2	932	1.77	2.87	1.77	2.32