ETHNOBIOLOGY LETTERS

Research Communication

The Paleobiolinguistics of Domesticated Manioc (*Manihot esculenta*)

Cecil H. Brown[1*], Charles R. Clement[2], Patience Epps[3], Eike Luedeling[4], and Søren Wichmann[5]

Author address: [1]Northern Illinois University, 1700 Scenic Highway, #601, Pensacola, FL, 32503-6634, USA, [2]Instituto Nacional de Pesquisas da Amazônia, Manaus, AM, Brazil, [3] University of Texas at Austin, Austin, TX, USA, [4]World Agroforestry Centre (ICRAF), Nairobi, Kenya, [5]Max Planck Institute for Evolutionary Anthropology, Leipzig, Germany.
[*]Corresponding author: brown.cecil@yahoo.com

Received: January 21, 2013
Published: June 26, 2013

Volume: 4:61-70

Abstract: *Paleobiolinguistics is used to identify on maps where and when manioc (*Manihot esculenta*) developed importance for different prehistoric groups of Native Americans. This information indicates, among other things, that significant interest in manioc developed at least a millennium before a village-farming way of life became widespread in the New World.*

Key Words: Archaeobotany, crop origins, historical linguistics, Native American Indians, paleobiolinguistics, plant domestication, plant genetics

Paleobiolinguistics (PBL) employs the comparative method of historical linguistics to reconstruct the biodiversity known to human groups of the remote, unrecorded past (Brown et al. 2013a; Brown et al. 2013b).[1] Comparison of words for biological taxa from languages of the same language family facilitates reconstruction of the biological vocabulary of the family's ancient proto-language. This study uses PBL to establish where and when domesticated manioc (*Manihot esculenta* Crantz, Euphorbiaceae) developed significance for different prehistoric Native American groups. This entails mapping in both time and geographic space proto-languages for which words for manioc reconstruct.

The approximately 98 species of *Manihot* are all native to the New World. There are two centers of diversity of *Manihot*. One is in Mesoamerica, which current evidence indicates may be the place of origin of the genus, with approximately 17 species; and the other is in Brazil, with approximately 80 species (Duputié et al. 2011). The only domesticated taxon is *M. esculenta* ssp. *esculenta*, which is derived from ssp. *flabellifolia*. This subspecies is widely distributed in tropical South America in seasonal open forests both north and south of the Amazon basin, and extending into the Brazilian savannas (Allem 2002). Work during the last decade establishes that ssp. *esculenta* was brought into domestication somewhere in what are today northwestern Mato Grosso, Rondônia, and eastern Acre, Brazil, and in immediately adjacent areas in lowland Bolivia (Schaal et al. 2006). Populations of ssp. *flabellifolia* in northern South America are shown by Léotard et al. (2009) not to be involved in domestication, and other species in Mesoamerica and South America are ruled out by Duputié et al. (2011).

Manioc can be lethally toxic if not prepared correctly. The presence of cyanogenic glucosides in the roots varies from less than 10 to more than 500 mg hydrogen cyanide (HCN) per kilo on a fresh weight basis; varieties with less than 100 mg/kg are considered sweet, and those with more are considered bitter (McKey et al. 2010) and require processing for consumption. While sweet and bitter varieties are difficult to distinguish morphologically, farmers typically are able to segregate bitter from sweet in their production systems (McKey and Beckerman 1993). Initial human selection probably favored the development of sweet varieties, which are more widely distributed in South America and through Central America to Mexico than bitter varieties (Arroyo-Kalin 2010). When food production systems started supplying significant proportions of human diets between 4000 and 3000 BP (Piperno and Pearsall 1998), bitter varieties were selected for toxicity to protect against pests and to provide higher yields (Arroyo-Kalin 2010). Bitter varieties are most common in Central and Eastern Amazonia and the Guianas, with sweet varieties being more prevalent in

Table 1. Manioc-term reconstruction for proto-languages of Mesoamerica (Southern Mexico and Northern Central America).

Years Before Present	Proto-Language	Proto-Word for Manioc (NR = Not Reconstructable)	Homeland Center Geographic Coordinates	Family Affiliation	Proto-Word Source
6591	Otomanguean	*ya	18, -96.92	Otomanguean	1
5498	Popolocan-Zapotecan	*ya	17.17, -96.17	Otomanguean	Authors
4274	Totozoquean	*pisi:	19.92, -97.42	Totozoquean	2
3149	Zapotecan	*ko: yaka	17.17, -96.17	Otomanguean	Authors
3036	Popolocan	*ya	18, -96.92	Otomanguean	Authors
2445	Chiapanec-Mangue	*yáʔ	17.07, -92.73	Otomanguean	3
2220	Mayan	*tz'ihn	15.42, -91.83	Mayan	4
1935	Chinantecan	*ʔma^{L}	17.92, -96.5	Otomanguean	5
1676	Zapotec	ko yaka	17.17, -96.17	Otomanguean	Authors
1649	Quichean-Mamean	*tz'iin	15.42, -91.83	Mayan	4
1596	Mixe-Zoquean	*pisi	17.22, -96.03	Totozoquean	6
1520	General Aztec	*k^{w}aw-kamoʔ	18.35, -99.83	Uto-Aztecan	Authors
1492	Greater Mamean	*tz'iin	15.42, -91.83	Mayan	4
1435	Totonacan	*qoqšqᵩwi̯	19.92, -97.42	Totozoquean	7
1432	Cholan-Tzeltalan	*tz'ihn	16.83, -92.83	Mayan	4
1225	Kanjobalan-Chujean	*tz'iin	15.83, -91.83	Mayan	4
1148	Cholan	*tz'ihn	14.81, -89.38	Mayan	4
1058	Chujean	*tz'in	15.92, -91.58	Mayan	4
997	Chatino	*ko: yaka	16.25, -97.38	Otomanguean	Authors
981	Greater Quichean	*tz'iin	14.78, -91.5	Mayan	4
900	Mixe	*kuhy-piši	17.02, -96.07	Totozoquean	6
802	Kanjobalan	*tz'iin	15.83, -91.83	Mayan	4
790	Yucatecan	*tz'iin	20, -89	Mayan	4
787	Zoque	*pisi	16.9, -94.68	Totozoquean	6
511	Tzeltalan	*tz'in	16.83, -92.83	Mayan	4

Proto-Word Source:
1. Kaufman 1990
2. Brown et al. 2011
3. Rensch 1976
4. Brown and Wichmann 2004
5. Rensch 1989
6. Wichmann 1995
7. David Beck, pers. com.

the basin's headwaters (McKey and Beckerman 1993). Bitter varieties were also once common along coastal Brazil, but now are rare.

Isendahl (2011) reviews the archaeobotanical evidence for cultivated manioc, with oldest dates of approximately 8000 BP for remains from the Pacific coast of Peru and low-elevations of the Colombian Andes, 5000 BP for lowland Amazonian Colombia, 7000 BP for Panama, and 6500 BP for Mexico. Arroyo-Kalin (2010) cautions that early dates for manioc may not always be *M. esculenta*, since the genus is widely distributed and other species may have been brought into domestication and later abandoned with the arrival of modern manioc. However, given that other *Manihot* species are absent from coastal Peru and the Colombian Andes (Duputié et al. 2011), the

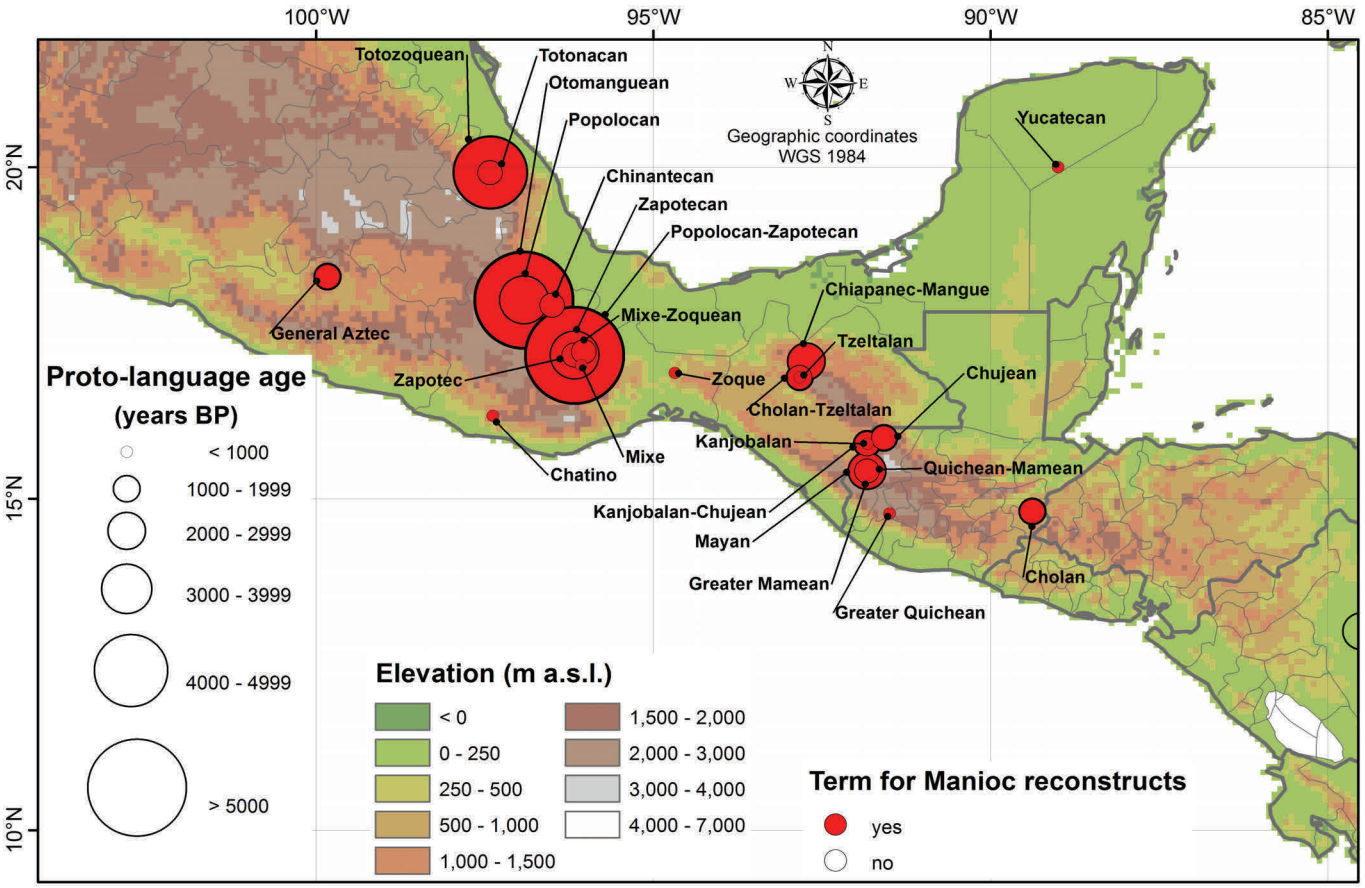

Figure 1. Manioc-term reconstruction information from Table 1 plotted on map of Mesoamerica.

earliest dates in these regions are likely to represent the introduction of *M. esculenta* from its center of domestication in southwestern Amazonia.

Manioc-term reconstructions are presented for proto-languages of two major regions of the New World: (1) Southern Mexico and Northern Central America (henceforth Mesoamerica) (Table 1); (2) Southern Central America and South America (Table 2). North America is not included in this analysis because manioc was a historical introduction there.

The tables list major proto-languages of the Americas widely regarded by historical linguists as demonstrated. Some major proto-languages are not included because lexical information from daughter languages is not sufficiently available for drawing either positive or negative conclusions about manioc-term reconstruction. Unfortunately, words for sweet and bitter varieties are insufficiently recorded in sources to permit a reconstructed distinction. In addition to identifying proto-languages with manioc terms and the terms themselves, the tables report proto-languages for which these terms are "not reconstructable" (NR). NR is a designation used when terms for manioc are present in all or most languages of a family, but, nonetheless, are not cognate and, hence, do not attest to a manioc term in their shared ancestral language. NR, then, never indicates that a term does not reconstruct because of missing data.

Dates for proto-languages presented in the tables are intended to be the latest dates at which these languages were spoken just before breaking up into daughter languages. These are calculated through use of Automated Similarity Judgment Program (ASJP) chronology, a computational dating approach based on the lexical similarity of languages (Holman et al. 2011).[2] Possible geographic coordinates for proto-language homeland centers given in the tables are produced through automation using an algorithm for identifying the maximum lexical diversity within a language family (Wichmann et al. 2010). The geographic center of lexical diversity of a family is assumed to correlate with where the family's proto-language was spoken. Tables also give a linguistic

Table 2. Manioc-term reconstruction for proto-languages of Southern Central America and South America.

Years Before Present	Proto-Language	Proto-Word for Manioc (NR = Not Reconstructable)	Homeland Center Geographic Coordinates	Family Affiliation	Proto-Word Source
7266	Macro-Ge	NR	-11.3, -53	Macro-Ge	
4701	Mataco-Guaykuru	NR	-22.5, -62.58	Mataco-Guaykuru	
4461	Southern Arawakan	*kaniri	-10.33, -74.33	Arawakan	Authors
4400	Chibchan	*ʔik, *ike	9.75, -83.42	Chibchan	1, 2
4134	Arawakan	*kani[tʰɨ]	1, -69.17	Arawakan	3
4085	N Arawakan	*kani[ti]	1, -69.17	Arawakan	Authors
3943	Panoan-Tacanan	NR	-7.5, -75	Panoan-Tacanan	
3585	Tupi	*mani	-8, -62	Tupi	4
3518	Caribbean N Arawakan	*kani	12, -72	Arawakan	Authors
3310	Salivan	NR	5, -67	Salivan	
3241	Barbacoan	*ku-	0.67, -79	Barbacoan	Authors
3178	Zaparoan	*murɨha	-3.25, -74	Zaparoan	5
3124	Nadahup	NR	0, -69	Nadahup	
3023	Ge	*kwyr	-15, -52.5	Macro-Ge	6
2927	Witoto-Ocaina	*hõʔti	-2.75, -71.75	Witoto-Ocaina-Nonuya	7
2909	Guaykuruan	NR	-26.5, -59	Mataco-Guaykuru	
2857	Witoto-Ocaina-Nonuya	*hoʔtit	-1.25, -72.5	Witoto-Ocaina-Nonuya	8
2807	Nambiquaran	*(wv^{3})lin’^{3}	-12.75, -59.17	Nambiquaran	9
2774	Misumalpan	NR	13, -84.5	Misumalpan	
2731	Talamancan	*ik	9.75, -83.42	Chibchan	Authors
2699	Tucanoan	*kɨi	0.33, -70.25	Tucanoan	10
2593	Inland N Arawakan	*kainhi, *kap(w)a-li, *mulhui	1, -69.17	Arawakan	11
2503	Venezuelan Cariban	*kɨčere, *amaka	6.5, -66	Cariban	Authors
2433	Southern Guaykuruan	*piyok	-26.5, -59	Mataco-Guaykuru	Authors
2414	North Barbacoan	*ku-	1.5, -78.25	Barbacoan	Authors
2412	Cariban	*kï(č/t)ere, *wïj(u)	10.17, -72.75	Cariban	12
2404	Matacoan	NR	-22.5, -62.58	Mataco-Guaykuru	
2271	Boran	*pɨɨkkaá, *paikoómɨ	-2.17, -72.33	Boran	7, Authors
2219	Purus	*kanɯrɯ	-12.5, -69.33	Arawakan	Authors
2156	Western Tucanoan	*kɨi	-2.83, -72.5	Tucanoan	Authors
1931	Chapacuran	*ʔakop	-13.43, -63.17	Chapacuran	13
1853	Panoan	*ʔatsa	-7.5, -75	Panoan-Tacanan	Authors
1853	Pekodian	*u	-14, -55	Cariban	Authors
1850	Tupari	*mani	-12.5, -62.5	Tupi	Authors

(continued on next page)

(continued from previous page)

Years Before Present	Proto-Language	Proto-Word for Manioc (NR = Not Reconstructable)	Homeland Center Geographic Coordinates	Family Affiliation	Proto-Word Source
1821	Southern Ge	*kɯbɛ{d}, *kagre	-26, -52	Macro-Ge	14
1780	Mascoian	*seppo	-23.2, -58	Mascoian	Authors
1764	Arauan	*po'a, *ximeka, *kojo	-6, -70.5	Arauan	15
1717	Quechuan	NR	0.33, -78	Quechuan	16
1712	Monde	NR	-10.97, -61.13	Tupi	
1634	Mainline Panoan	*ʔatsa	-7.5, -75	Panoan-Tacanan	17
1607	Jabuti	*murɛ	-12.25, -62.25	Macro-Ge	18, 19
1590	Tacanan	*kwawe	-13.33, -66.5	Panoan-Tacanan	20
1569	Harakmbet	*táare	-12.5, -70.5	Harakmbet	21
1550	Tupi-Guarani	*mani	-8, -62	Tupi	5
1519	Kampan	*kaniri	-10.33, -74.33	Arawakan	Authors
1480	Munduruku	*masɨk	-7, -58	Tupi	Authors
1418	Cayapa-Colorado	*kuhcu	0.67, -79	Barbacoan	22
1402	Guianan Cariban	*kičere, *wɨi	3.25, -55.75	Cariban	Authors
1395	Cabecar-Bribri	*ali	9.42, -83	Chibchan	Authors
1335	Kakua-Nukak	*tũj	0.88, -69.56	Kakua-Nukak	Authors
1319	Yanomam	*naši	3.5, -62.83	Yanomam	Authors
1291	Guahiban	*newa, *bawá	6.5, -71.33	Guahiban	23, Authors
1262	Timbira	*kwɨr	-5.25, -46	Macro-Ge	18
1241	Eastern Tucanoan	*kɨi	0.33, -70.25	Tucanoan	Authors
1185	Kawapanan	*kiʔ	-5.5, -77	Kawapanan	24
1169	Pemongan	*kɨsera	4, -60	Cariban	Authors
992	Taranoan	*wɨi	1, -73	Cariban	25
974	Quechua II	*rumu	0.33, -78	Quechuan	16
678	Jivaroan	*máma	-2.5, -78	Jivaroan	26
644	Guaymi	*ho, *hi	8.67, -82	Chibchan	Authors
419	Coconucan	*lo	2.5, -76.5	Barbacoan	Authors
414	Witoto Proper	*huti, *maika(hi)	-1, -73.5	Witoto-Ocaina-Nonuya	Authors
389	Mayoruna Panoan	*ʔatsa	-4.42, -70.25	Panoan-Tacanan	Authors

Proto-Word Source:

1. Constenla 1981
2. Constenla 1990
3. Payne 1991
4. Rodrigues 2010
5. Lev Michael, pers. com.
6. Davis 1966
7. Aschmann 1993
8. Echeverri and Seifart 2011
9. Price 1978
10. Chacon n.d.
11. Ramirez 2001
12. Sergio Meira, pers. com.
13. Angenot-de Lima 1997
14. Jolkesky 2010
15. Dixon 2004
16. Willem Adelaar, pers. com.
17. Shell 2008
18. Eduardo Ribeiro, pers. com
19. van der Voort 2007
20. Girard 1971
21. Matteson 1972
22. Moore 1962
23. Christian and Matteson 1972
24. Pilar Valenzuela, pers. com.
25. Meira 2000
26. Payne 1981

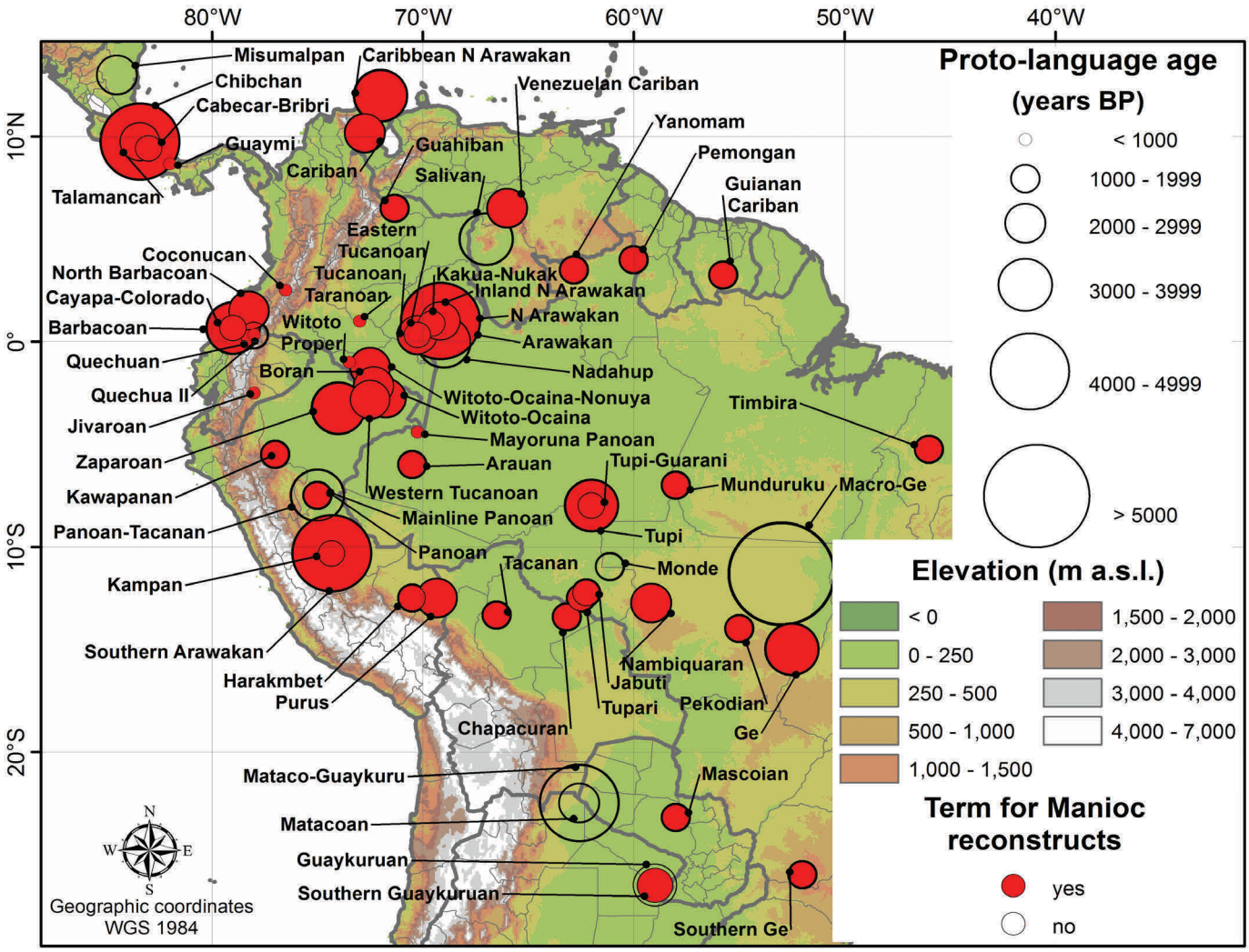

Figure 2. Manioc-term reconstruction information from Table 2 plotted on map of Southern Central America and South America.

family affiliation for each proto-language. The information reported in Tables 1 and 2 is plotted on maps of Figures 1, 2 and 3 to give a visual perspective on both the chronological and geographic distributions of reconstructed manioc terms. Figure 3 is an enlargement of a highly congested area of the map of Figure 2.

As noted above, manioc was originally domesticated somewhere in southwestern Amazonia (Schaal et al. 2006). This area includes the presumed Tupi homeland (Noelli 1998; Rodrigues 1964; Walker et al. 2012; and see Figure 2). Nevertheless, the ASJP date for Proto-Tupi is somewhat more recent (3585 BP, Table 2) than dates for other South American groups, especially Arawakan (4461-4085 BP, Table 2). The Arawakan homeland is near the 5000 BP-manioc remains reported from lowland Colombian Amazonia (Isendahl 2011) and, thus, appears to reflect the dispersal of the crop from its center of domestication. From PBL analysis, there is no direct indication that speakers of any particular South American proto-language were responsible for manioc domestication.

While archaeological evidence attests to the presence of manioc in Central America as early as 7000 BP (Isendahl 2011), the earliest date for a proto-language in the area having a manioc term, i.e., Chibchan, is 4400 BP (Table 2). This 2600-year discrepancy may be more apparent than real considering, for example, that ASJP dates are minimum dates for proto-languages, i.e., latest dates at which ancestral languages were still spoken. The date for Otomanguean, 6591 BP (Table 1), of northern Mesoamerica, corresponds well with the archaeological date of 6500 BP for the earliest remains of manioc in the area

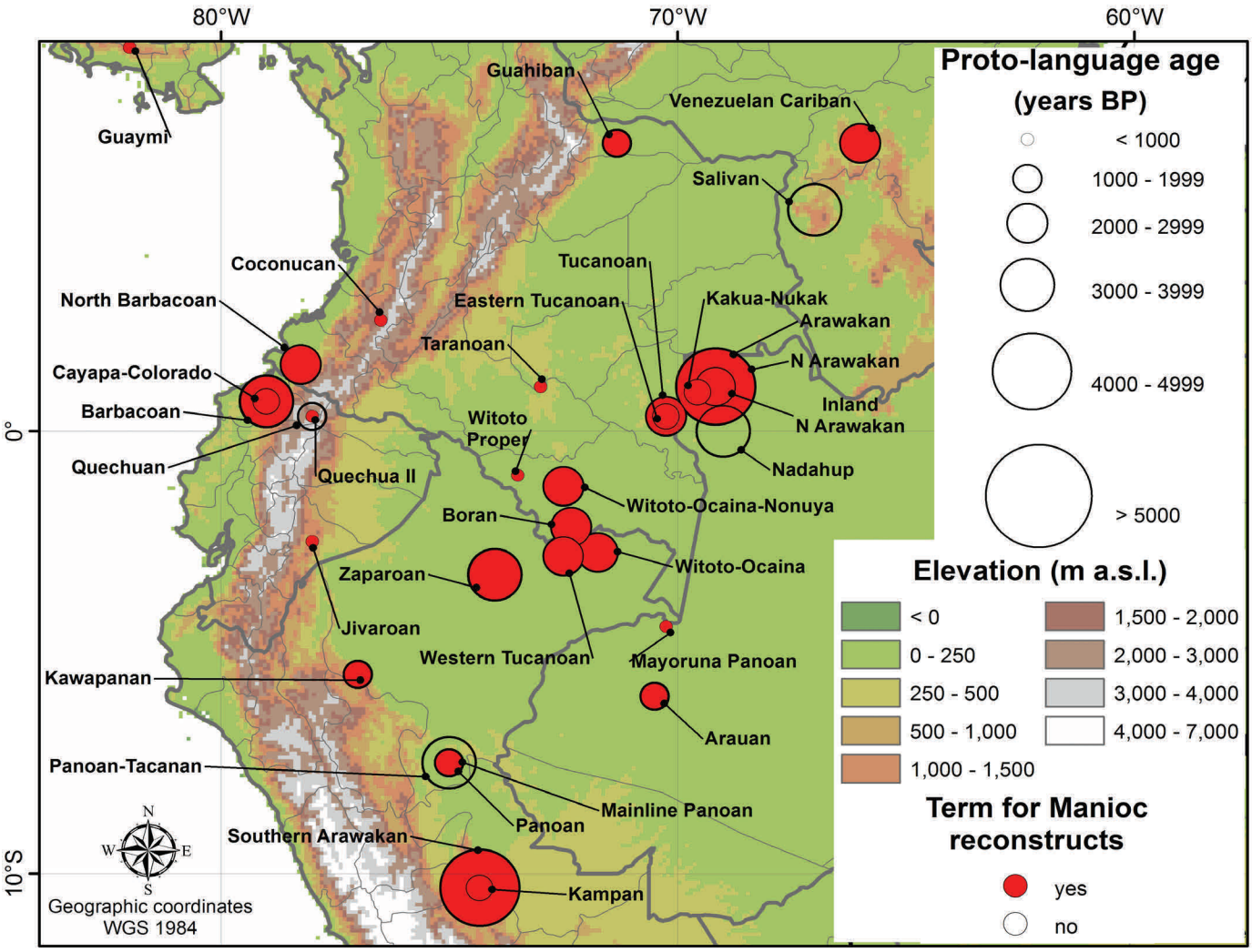

Figure 3. Enlargement of congested region (northwestern South America and adjacent areas) of map of Figure 2.

(Isendahl 2011). Notably, manioc reconstructs for all proto-languages of Mesoamerica (Figure 1), while this is not so for those of southern Central America and South America (Figure 2).

In general, proto-languages for which manioc terms reconstruct are broadly distributed through lowland South America and Mesoamerica, reflecting the crop's dispersal throughout the Neotropics from its origin in southwestern Amazonia. ASJP dates for these proto-languages, like archaeobotanical ones, indicate that domestication and dispersal of the crop occurred before the general development of a village-farming way of life in the New World from 4000 to 3000 BP (Piperno and Pearsall 1998; Smith 1992).

Acknowledgements

We thank Jan Salick, Doyle McKey, Manuel Arroyo-Kalin, Christian Isendahl, two anonymous reviewers, and the editors for useful suggestions for improving this study. We are also grateful to Willem Adelaar, David Beck, Sergio Meira, Lev Michael, Eduardo Ribeiro, and Pilar Valenzuela for supplying linguistic data.

Declarations

Permissions: Not applicable.

Sources of funding: Epps' work on this project was supported by the National Science Foundation (HSD0902114).

Conflicts of interest: None declared.

References Cited

Allem, A. C. 2002. The Origins and Taxonomy of Cassava. In *Cassava, Biology, Production and Utilization*, edited by R. J. Hillocks, J. M. Thresh, and A. C. Belloti, pp. 1-16. CAB International, Wallingford, UK.

Angenot de Lima, M. G. 1997. Fonotática e Fonologi do Lexema Protochapakura. Unpublished Master's Thesis, Universidade Federal de Rondônia.

Arroyo-Kalin, M. 2010. The Amazonian Formative: Crop Domestication and Anthropogenic Soils. *Diversity* 2:473-504.

Aschmann, R. P. 1993. *Proto Witotoan*. Summer Institute of Linguistics, Arlington, Texas.

Brown, C. H. 2006a. Glottochronology and the Chronology of Maize in the Americas. In *Histories of Maize: Multidisciplinary Approaches to the Prehistory, Biogeography, Domestication, and Evolutions of Maize*, edited by, J. E. Staller, R. H. Tykot, and B. F. Benz, pp. 648–663. Elsevier, San Diego.

Brown, C. H. 2006b. Prehistoric Chronology of the Common Bean in the New World: The Linguistic Evidence. *American Anthropologist* 108:507–516.

Brown, C. H. 2010. Development of Agriculture in Prehistoric Mesoamerica: The Linguistic Evidence. In *Pre-Columbian Foodways: Interdisciplinary Approaches to Food, Culture and markets in Ancient Mesoamerica*, edited by J. E. Staller and M. D. Carrasco, pp. 71–107. Springer Science+Business Media, Berlin.

Brown, C. H., D. Beck, G. Kondrak, J. K. Watters, and S. Wichmann. 2011. Totozoquean. *International Journal of American Linguistics* 77:323–372.

Brown, C. H., C. R. Clement, P. Epps, E. Luedeling, and S. Wichmann. 2013a. The Paleobiolinguistics of Chili Pepper (*Capsicum* spp.). *Ethnobiology Letters* 4:1-11.

Brown, C. H., E. Luedeling, S. Wichmann, and P. Epps. 2013b. The Paleobiolinguistics of Domesticated Squash (*Cucurbita* spp.). In *Explorations in Ethnobiology: The Legacy of Amadeo Rea*, edited by M. Quinlan and M. D. Lepofsky, pp. 132-161. Society of Ethnobiology, Denton, Texas.

Brown, C. H., and S. Wichmann. 2004. Proto-Mayan Syllable Nuclei. *International Journal of American Linguistics* 70:128–186.

Chacon, T. n.d. A Revised Proposal of Proto-Tukanoan Consonants and Tukanoan Family Classification. Forthcoming in *International Journal of American Linguistics*.

Christian, D. R., and E. Matteson. 1972. Proto Guahiban. In *Comparative Studies in Amerindian Languages*, edited by E. Matteson et al., pp. 150-159. Mouton, The Hague.

Constenla-Umaña, A. 1981. Comparative Chibchan Phonology.Unpublished Doctoral Dissertation, University of Pennsylvania.

Constenla-Umaña, A. 1990. Una Hipótesis sobre la Localización del Protochibcha y la Dispersión de sus Descendientes. *Revista de Filología y Lingüística de la Universidad de Costa Rica* 16:111–123.

Davis, I. 1966. Comparative Jê Phonology. *Estudos Lingüísticos* 1:10-24.

Dixon, R. M. W. 2004. Proto-Arawá Phonology. *Anthropological Linguistics* 46:1-83.

Echeverri, J. A. and F. Seifart. 2011. Una Re-evaluación de las Familias Lingüísticas Bora y Witoto. Paper Presented at Congreso Arqueología y Lingüística Histórica de las Lenguas Indígenas Sudamericanas, Universidad de Brasília.

Duputié, A., J. Salick, and D. McKey. 2011. Evolutionary Biogeography of *Manihot* (Euphorbiaceae), a Rapidly Radiating Neotropical Genus Restricted to Dry Environments. *Journal of Biogeography* 38:1033-1043.

Girard, V. 1971. *Proto-Takanan Phonology*. University of California Press, Berkeley.

Holman, E. W., C. H. Brown, S. Wichmann et al. 2011. Automated Dating of the World's Language Families based on Lexical Similarity. *Current Anthropology* 52:841-875.

Isendahl, C. 2011. The Domestication and Early Spread of Manioc (*Manihot esculenta* Crantz): a Brief Synthesis. *Latin American Antiquity* 22:452-468.

Jolkesky, M. P. V. 2010. Reconstrução Fonológica e Lexical do Proto-Jê Meridional. Unpublished Master's Thesis, Universidade Estadual de Campinas.

Kaufman, T. S. 1990. Early Otomanguean Homeland and Cultures: Some Premature Hypotheses. *University of Pittsburgh Working Papers in Linguistics* 1:91–136.

Léotard, G., A. Duputié, F. Kjellberg, E. J. P. Douzery, C. Debain, J. J. de Granville, and D. McKey. 2009. Phylogeography and the Origin of Cassava: New Insights from the Northern Rim of the Amazon Basin. *Molecular Phylogenetics and Evolution* 53:329-334.

Meira, S. 2000. *A Reconstruction of Proto-Taranoan: Phonology and Morphology*. Lincom Europa, München.

McKey, D., and S. Beckerman. 1993. Chemical Ecology, Plant Evolution and Traditional Manioc Cultivation Systems. In *Tropical Forests, People and Food: Biocultural Interactions and Applications to Development*, edited by C. M. Hladik, A. Hladick, O. F. Linares, H. Pagezy, A. Semple, and M. Hadley, pp. 83-112. Parthenon, Carnforth, UK, and UNESCO, Paris, France.

McKey, D., T. R. Cavagnaro, J. Cliff, and R. Gleadow. 2010. Chemical Ecology in Coupled Human and Natural Systems: People, Manioc, Multitrophic Interactions and Global Change. *Chemoecology* 20:109 -133.

Moore, B. R. 1962. Correspondences in South Barbacoan Chibcha. In *Studies in Ecuadorian Indian Languages: I*, edited by C. Peeke, pp. 270-289. Summer Institute of Linguistics, Norman, Oklahoma.

Noelli, F. 1998. The Tupi: Explaining origin and Expansions in Terms of Archaeology and of Historical Linguistics. *Antiquity* 72:648-663.

Payne, D. L. 1981. Bosquejo Fonológico del Proto-shuar-candoshi: Evidencia para una Relación Genética. *Revista del Museo Nacional* 16:323-77.

Payne, D. L. 1991. A Classification of Maipuran (Arawakan) Languages Based on Shared Lexical Retentions. *Handbook of Amazonian Languages* 3:355-499.

Piperno, D. R., and D. M. Pearsall. 1998. *The Origins of Agriculture in the Lowland Neotropics*. Academic Press, San Diego.

Price, P. D. 1978. The Nambiquara Linguistic Family. *Anthropological Linguistics* 20:14-37.

Ramirez, H. 2001. *Línguas Arawak da Amazonia Setentrional*. Editora da Universidade do Amazonas, Manaus.

Rensch, C. R. 1976. *Comparative Otomanguean Phonology*. Indiana University Publications, Bloomington.

Rensch, C. R. 1989. *An Etymological Dictionary of the Chinantec Languages*. Summer Institute of Linguistics, Arlington, Texas.

Rodrigues, A. 1964. A Classificação do Tronco Lingüístico Tupi. *Revista de Antropologia* 12:99-104.

Rodrigues, A. 2010. Linguistic Reconstruction of Elements of Prehistoric Tupi Culture. In *Linguistics and Archaeology in the Americas: The Historization of Language and Society*, edited by Eithne B. Carlin and Simon van de Kerke, pp. 1-10. London: Brill.

Schaal, B. A., K. M. Olsen, and L. J. C. B. Carvalho. 2006. Evolution, Domestication, and Agrobiodiversity in the Tropical Crop Cassava. In *Darwin's Harvest: New Approaches to the Origins, Evolution, and Conservation of Crops*, edited by T. J. Motley, N. Zerega, and H. Cross, pp. 269-284. Columbia University Press, New York.

Shell, O. A. 2008. *Estudios Pano III: Las Lenguas Pano y su Reconstrucción.* Instituto Lingüístico de Verano, Lima, Perú.

Smith, Bruce D. 1992. *Rivers of Change: Essays on Early Agriculture in Eastern North America.* Smithsonian Institution Press, Washington, D.C.

Voort, H. van der. 2007. Proto-Jabutí: Um Primeiro Passo na Reconstrução da Língua Ancestral dos Arikapú e Djeoromitxí. *Bol. Mus. Para. Emílio Goeldi. Ciências Humanas* 2:133-168.

Walker, R. S., S. Wichmann, T. Mailund, and C. J. Atkisson. 2012. Cultural Phylogenetics of the Tupi Language Family in Lowland South America. *PLoS ONE* 7(4): e35025. doi:10.1371/journal.pone.0035025

Wichmann, S. 1995. *The Relationship among the Mixe-Zoquean Languages of Mexico*. University of Utah Press, Salt Lake City.

Wichmann, S., A. Müller, and V. Velupillai. 2010. Homelands of the World's Language Families: A Quantitative Approach. *Diachronica* 27:247–276.

Biosketches

Cecil H. Brown is a linguistic anthropologist with interests in ethnobiology, historical linguistics, and Native American languages.

Charles R. Clement is a geneticist studying the origin and domestication of native Amazonian crops, and the ethnobotany associated with anthropogenic soils and

other domesticated landscapes.

Patience Epps is a linguist whose work investigates lowland South American languages from historical, typological, and descriptive perspectives.

Eike Luedeling is an agricultural scientist mainly concerned with projection of climate change impacts on agricultural and natural ecosystems and with the development of appropriate adaptation strategies.

Søren Wichmann specializes in quantitative methods in historical linguistics and Mesoamerican languages. He is General Editor of the journal *Language Dynamics and Change*.

Notes

[1]This is the second PBL study published in *Ethnobiology Letters*, the first treating chili pepper (Brown et al. 2013a). Several others are projected. The method and theory of PBL is summarized in Brown et al. (2013a) and discussed in substantial detail in several preceding papers (Brown 2006a,b; Brown 2010; Brown et al. 2013b). The current paper and others that follow in *Ethnobiology Letters* will not repeat these discussions.

[2]Occasionally, an ASJP date for a proto-language may be older than a date for its own parent language. For example, Proto-Southern Arawakan (4461 BP) has an ASJP date older than that for Proto-Arawakan (4134 BP). This sometimes occurs in ASJP chronology when a language group's breakup is closely followed in time by the breakup of its immediate subgroup. The attested variability of ASJP dates accounts for this apparent aberrancy (Holman et al. 2011:872).