

Perennial Vegetables:

Biodiversity, Carbon Sequestration and Nutrition

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A Neglected and Underutilized Class of Crops

- How many are there?
- What's their potential climate impact?
- How nutritious are they?

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RESEARCH ARTICLE

Perennial vegetables: A neglected resource for biodiversity, carbon sequestration, and nutrition

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Abstract

Perennial vegetables are a neglected and underutilized class of crops with potential to address 21st century challenges. They represent 33–56% of cultivated vegetable species, and occupy 6% of world vegetable cropland. Despite their distinct relevance to climate change mitigation and nutritional security, perennial vegetables receive little attention in the scientific literature. Compared to widely grown and marketed vegetable crops, many perennial vegetables show higher levels of key nutrients needed to address deficiencies. Trees with edible leaves are the group of vegetables with the highest levels of these key nutrients. Individual “multi-nutrient” species are identified with very high levels of multiple nutrients for addressing deficiencies. This paper reports on the synthesis and meta-analysis of a heretofore fragmented global literature on 613 cultivated perennial vegetables, representing 107 botanical families from every inhabited continent, in order to characterize the extent and potential of this class of crops. Carbon sequestration potential from new adoption of perennial vegetables is estimated at 22.7–280.6 MMT CO₂-eq/yr on 4.6–26.4 Mha by 2050.

Figures



Definition

- Perennial
 - 3-3,000 years
 - Including woody species and vines
- Primary use is cooking or using raw in salads
 - VEGETATIVE: leaves, shoots, stems
 - REPRODUCTIVE: flowerbuds, flowers, ripe or unripe fruit, unripe seeds
- NOT
 - Primarily used as a culinary herb
 - Staple crops like bananas and root crops
 - Dessert fruits like strawberries and melons



Crambe maritima

Benefits & Tradeoffs

Benefits	Tradeoffs
<ul style="list-style-type: none">• Species for niches where annual vegetables won't grow• Season extension• Many resist pests and diseases• No-till after establishment• Climate change adaptation• Many well-suited to agroforestry systems	<ul style="list-style-type: none">• Some hard to acquire• Some more expensive• Viruses and other diseases• Some unfamiliar flavors and textures• Some potential weeds



Cercis canadensis

Season of Harvest – Paradise Lot

	November to March	April	May	June	July to September	October
Perennial shoots		Asparagus, milkweed, <i>Hablitzia</i> , hosta	asparagus, <i>Hablitzia</i> , bamboo			
Herbaceous perennial leaves	Korean celery	Scallions, garlic chives	Milkweed, scallions, garlic chives, sylvetta	<i>Hablitzia</i> , scallions, sylvetta		Korean celery, sylvetta, scallions
Aquatic perennial leaves		Water celery, cattail	Water celery, arrowhead	Arrowhead	Arrowhead	
Coppiced woody leaf crops			Goji, grape leaf	Goji, mulberry, Chinese toon, linden, grape leaf	Goji, mulberry, Chinese toon, linden, grape leaf	
Perennial greenhouse leaves	Perennial kales	Perennial kale, vegetable fern	Vegetable fern	Vegetable fern	Vegetable fern	Perennial kale, vegetable fern
Flowers & broccolis			redbud, sea kale, Turkish rocket	Milkweed	Garlic chives	
Perennial fruit vegetables			Siberian elm		Milkweed	Ground cherry
Annual crops			Various leaf crops	Various leaf crops	Various fruits and leaves	
Winter greenhouse annuals	Various leaf crops	Various leaf crops				Various leaf crops



Biodiversity

Broadening the base of food security

Agricultural Biodiversity Crisis

- 80% of crop production is from 17 families
 - 12 families of vegetables
- 107 families of cultivated PVs
 - 63 among those suited to Europe



Findings

- 35-56% of cultivated vegetable species are PVs
- 7.7% of all cultivated crops are PVs
- 613 cultivated species globally
 - 251 cult spp. for warm temp, cold temp, boreal, arctic
 - 101 cultivated native PV species from Europe

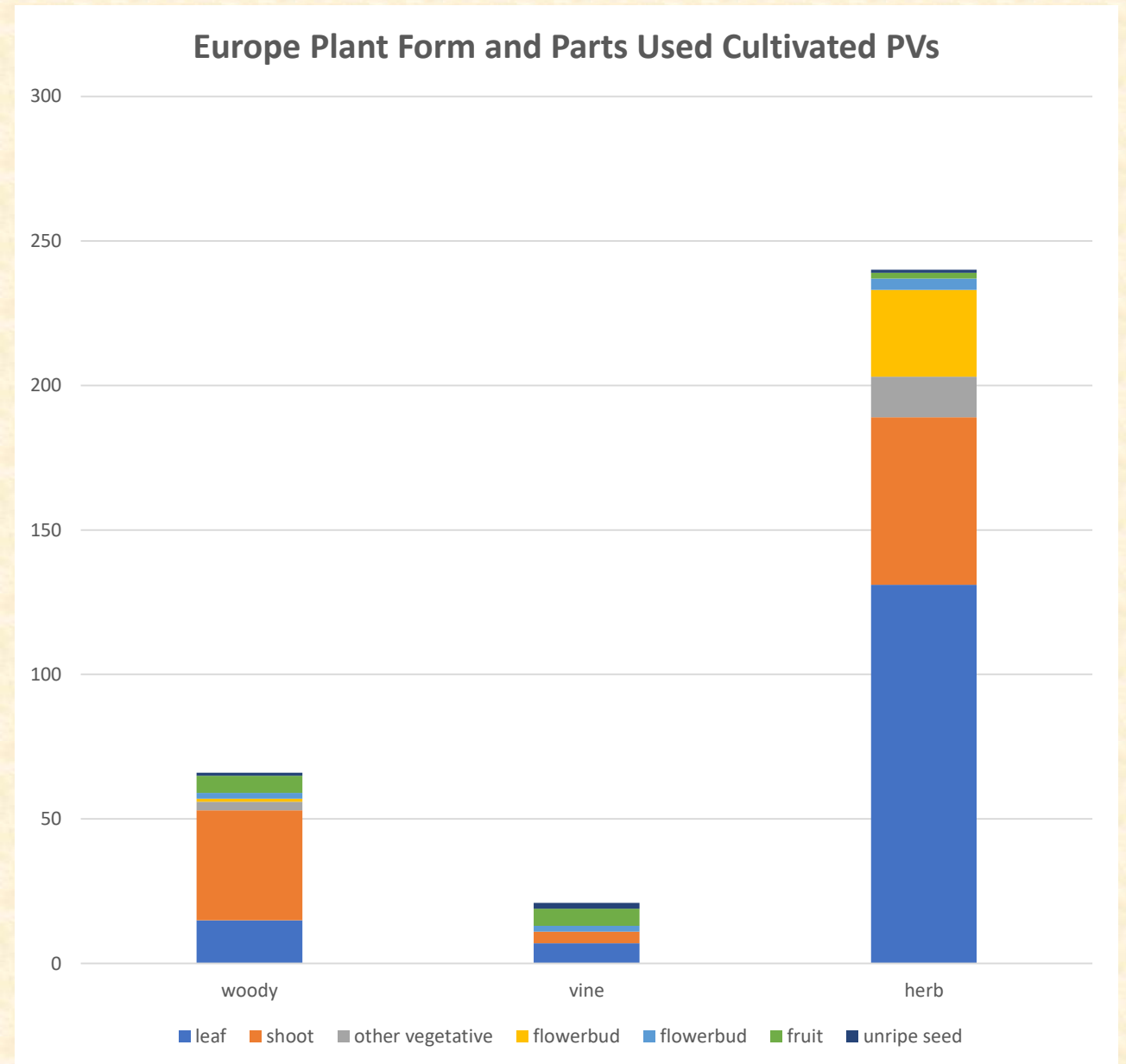
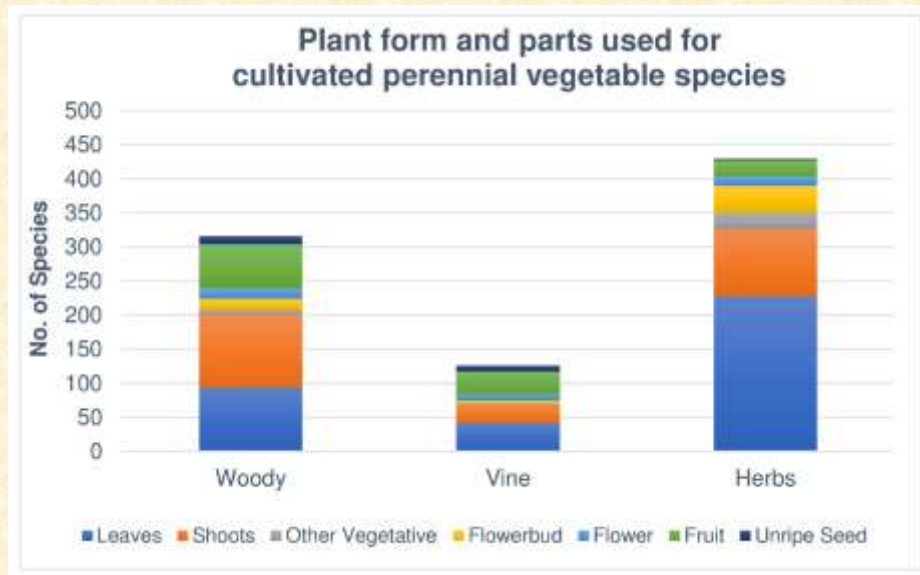


Findings from Mexico

- Analyzing native PVs of Mexico
 - Cultivated and wild
- 2.25% of all Mexican plant species are PVs
- If applied to globe, 7,882 species of PVs including cult and wild
- Found 23 additional cultivated species
 - If same % missed globally, 287 additional spp
 - 901 global cult PV spp estimated

Form and Habit

Global



Carbon Sequestration

Contributing to the Perennialization of Agriculture

Sequestration Rates by Type

Table 1. Carbon sequestration rates of PVs.

PV Category	PV production system type	Sample species or system	Sequestration rate MgC/ha/yr	Source
Woody perennial crops	Orchard and plantation; full-sized woody plants for flowers, fruits, and unripe seeds	Convert cropland to orchard	3.5	[54]
		<i>Olea europaea</i>	2.6	[55]
		<i>Bactris gasipaes</i>	5.1	[56]
		<i>Dacryodes edulis</i>	7.8	[57]
		Tree crops–temperate	2.1	[58]
		Tree crops–tropical	1.8–10.0	[58]
	Bamboo for shoot production	Bamboo plantations	6.0–13.0	[59]
	Coppiced woody plants for edible leaves	Fodder tree blocks	0.1–0.5	[54]
		Short rotation coppice	1.18	[60]
	Average sequestration rate		3.71	
Perennial vines and herbaceous crops	Perennial vines	<i>Vitis vinifera</i>	0.3–0.8	[61]
	Robust perennial herbs (over 2m height)	Giant biomass grasses	1	[62]
		Perennial grains	0.3–0.5	[63]
	Ordinary perennial herbs (under 2m height)	Residential landscape with herbaceous perennials	0.0–0.1	[64]
	Average sequestration rate		0.43	

Global Sequestration Potential

- 22.7-280.6 MMT CO₂-eq/yr in 2050 globally
 - Between impacts of restoring coastal wetlands and hybrid cars
- Variables
 - Does vegetable expansion triple to meet the world's nutrition needs?
 - How much emphasis is placed on woody PVs?
- A higher impact than improved annual cropping systems alone



Olea europaea Image Petr Pakandl CC BY-SA 2.5

Nutrition

The World Must Triple Vegetable Production to Meet Nutrient Needs

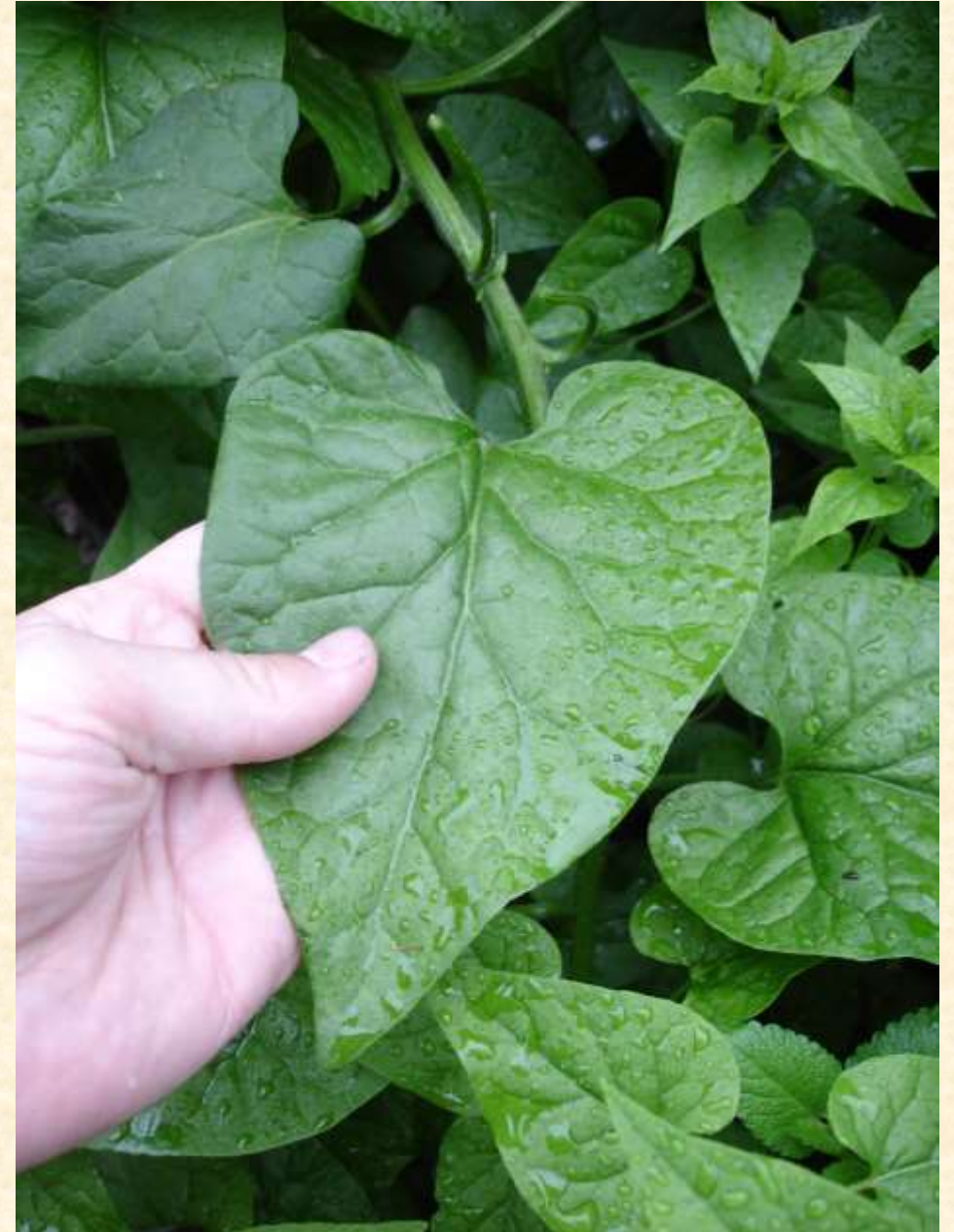
Industrial Diet Deficiencies

Deficiency	Health Impacts
Fiber	<ul style="list-style-type: none">• Heart disease• Obesity
Magnesium	<ul style="list-style-type: none">• Diabetes• High blood pressure• Heart disease
Calcium	<ul style="list-style-type: none">• Osteoporosis
Antioxidants like Vitamins A, C and E	<ul style="list-style-type: none">• Cardiovascular disease



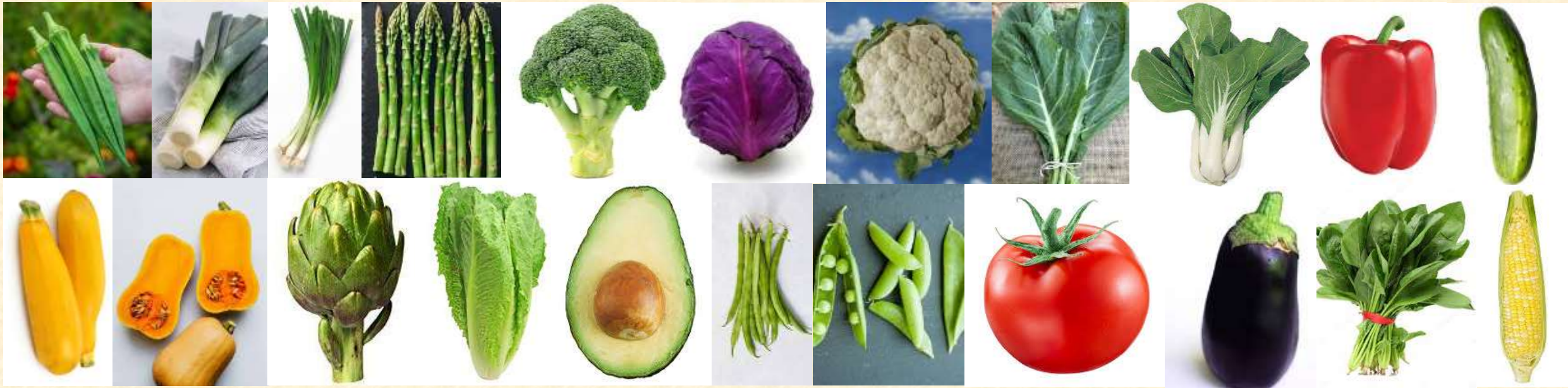
Research

- Nutrient data on 350 perennial and annual vegetables
- From 53 sources
- Many gaps
 - Species missing
 - Nutrients missing
- Fundraising for further research
- All available open access data



Hablitzia tamnoides







The Reference Crops



Superabundant: Higher than the highest levels reported in the reference vegetables

Multinutrient: Superabundant in more than one nutrient

European “Top Ten” Superabundant

Fiber	Calcium	Magnesium	Vitamin A	Vitamin C	Vitamin E
					
1. Runner bean (<i>Phaseolus coccineus</i>)	1. Saltbush (<i>Atriplex halimus</i>)	1. Saltbush (<i>Atriplex halimus</i>)	1. Goji fruit (<i>Lycium barbarum</i>)	1. Milkweed (<i>Asclepias syriaca</i>)	1. Chinese toon (<i>Toona sinensis</i>)
2. Grape leaf (<i>Vitis vinifera</i>)	2. Mulberry leaf (<i>Morus alba</i>)	2. Arctic willow (<i>Salix reticulata</i>)	2. Chinese toon (<i>Toona sinensis</i>)	2. Arugula, rocket (<i>Eruca vesicaria</i>)	2. Garland chrysanthemum (<i>Glebionis coronaria</i>)
3. Fava bean (<i>Vicia faba</i>)	3. Amaranth leaf (<i>Amaranthus retroflexus</i>)	3. Mulberry leaf (<i>Morus alba</i>)	3. Sow thistle (<i>Sonchus oleraceus</i>)	3. Winter cress (<i>Barbarea vulgaris</i>)	3. Hops shoots (<i>Humulus lupulus</i>)
4. Akkoub (<i>Gundelia tournefortii</i>)	4. African eggplant leaf (<i>Solanum aethiopicum</i>)	4. Grape leaf (<i>Vitis vinifera</i>)	4. Black nightshade (<i>Solanum americanum</i>)	4. Mulberry leaf (<i>Morus alba</i>)	4. Stinging nettle (<i>Urtica dioica</i>)
5. Korean celery (<i>Dystaenia takesimiana</i>)	5. Stinging nettle (<i>Urtica dioica</i>)	5. Ragged jack kale (<i>Brassica napus</i>)	5. Arctic willow (<i>Salix pulchra</i>)	5. Stinging nettle (<i>Urtica dioica</i>)	5. Bladder campion (<i>Silene vulgaris</i>)

Woody

Vine

Herb

Annual

Trees With Edible Leaves

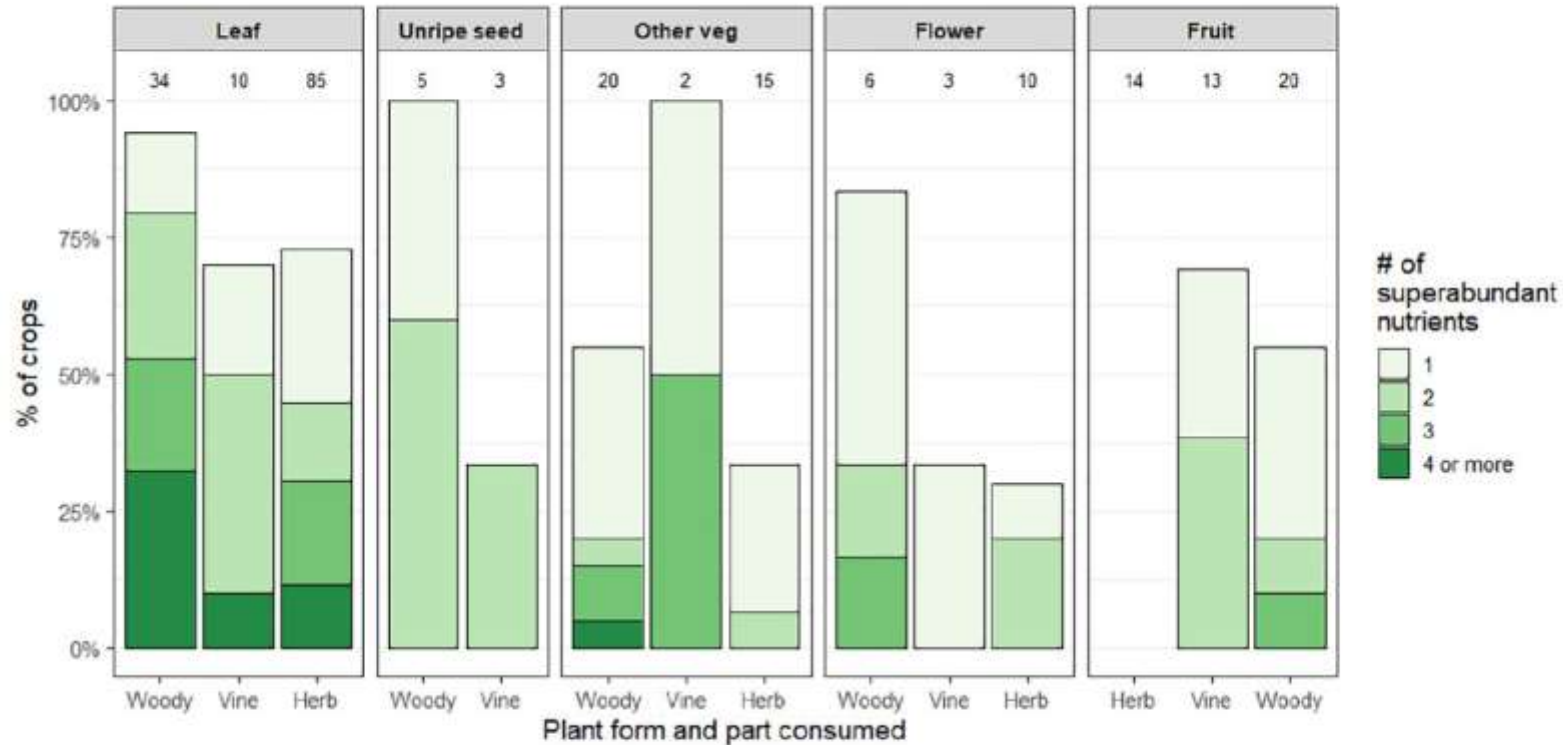


Fig 4. Proportions of perennial vegetables with one or more superabundant nutrients by plant form and part consumed. Nutrient levels are classified as superabundant when they are higher than the highest level of that nutrient among the reference vegetables. Here the percentage of crops with one or more superabundant nutrients is displayed for 240 perennial vegetables broken down by plant form and part used. The numbers of crops within each category are displayed along the top of the plot.

Multi-nutrient Species to Address Industrial Diet Deficiencies for Europe

Latin Name	Common Name	Part	Fiber	Calcium	Magnesium	Vitamin A	Vitamin C	Vitamin E
<i>Asclepias syriaca</i>	Milkweed	Leaf		VH		VH	XH	
<i>Atriplex halimus</i>	Saltbush	Leaf	VH	XH	XH			
<i>Chamerion angustifolium</i>	Fireweed	Shoot	H	H	VH		VH	
<i>Morus alba</i>	Mulberry	Leaf	VH	VH	VH	VH	VH	
<i>Silene vulgaris</i>	Bladder campion	Leaf	VH			VH		XH
<i>Toona sinensis</i>	Chinese toon	Leaf		VH		XH	VH	XH
<i>Urtica dioica</i>	Stinging nettle	Leaf	H	VH	H		VH	XH
<i>Vitis vinifera</i>	Grape	Leaf	XH	VH	VH	VH		H

Standout Species

Nutritional superstars for Europe

Chinese Toon

Toona sinensis

- Leaves
- Extremely high: Vitamins A and E
- Very high: calcium, Vitamin C
- Coppice management



Saltbush, Tree Purslane

Atriplex halimus

- Leaves
- Extremely high: calcium, magnesium
- Very high: fiber
- High in salt as well
- Hedgerow management



Edible-Leaf Mulberry

Morus alba

- Leaves
- Very high: fiber, calcium, magnesium, Vitamins A and C
- Coppice management



Goji, Edible-Leaf Goji

Lycium barbatum, *L. chinense*

- Fruit extremely high in Vitamin A
- Leaves extremely high in Vitamin E
- Coppice management for leaves



Grape Leaf

Vitis vinifera

- Leaves
- Extremely high in fiber
- Very high in calcium, magnesium, and vitamin A
- Coppice management or prunings of fruiting grapes



Stinging Nettle

Urtica dioica

- Shoots and leaves
- Extremely high in Vitamin E
- Very high in calcium and Vitamin C
- Herbaceous management, somewhat shade tolerant



Conclusions

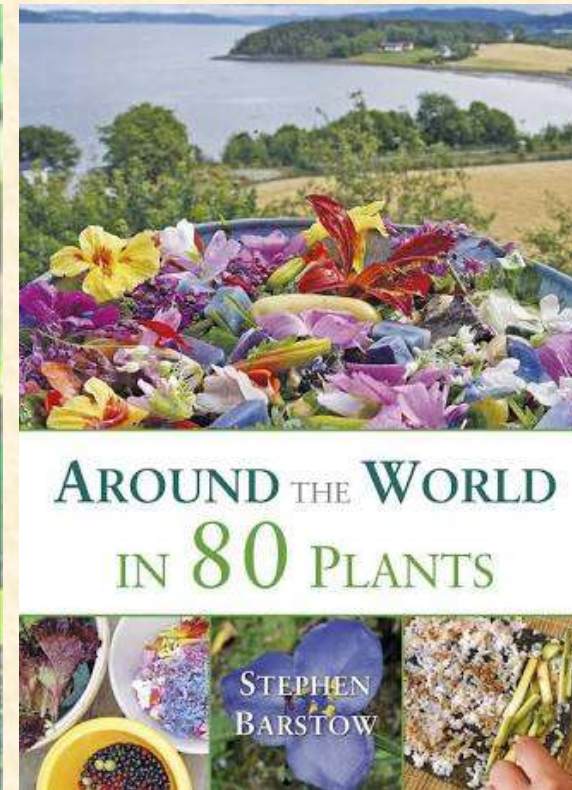
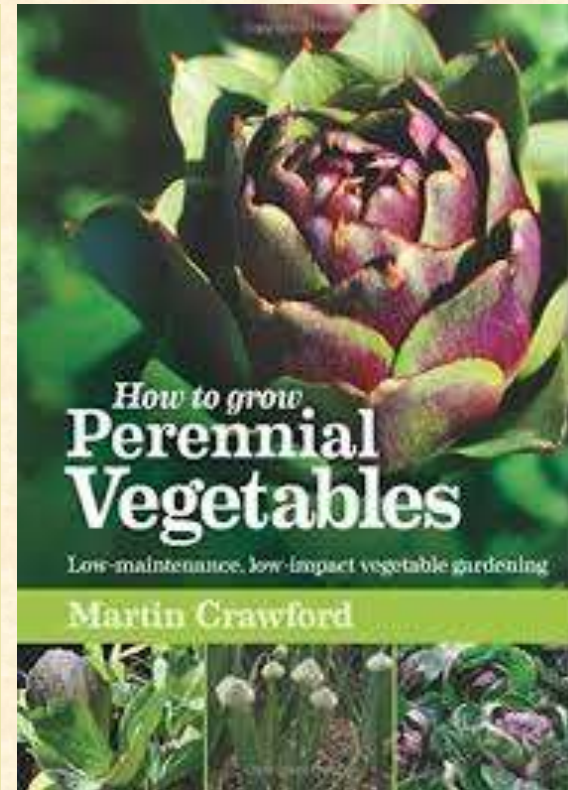
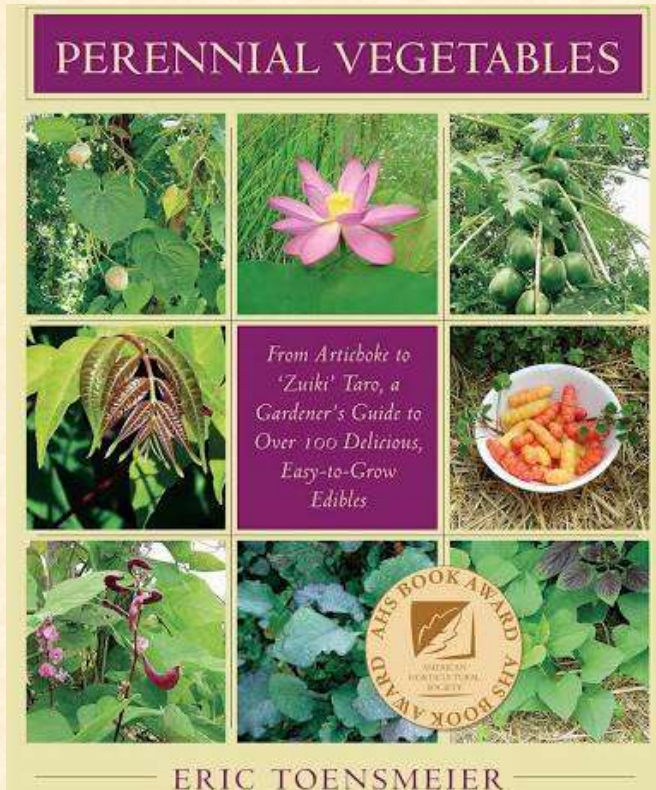
Facing Challenges with Perennial Vegetables

- Can increase agricultural biodiversity
- Can help perennialize agriculture and sequester carbon
- Can address nutrient deficiencies impacting millions of people in Europe
 - The species most widely grown and marketed are not the best to address these deficiencies
 - Many trees with edible leaves are outstanding



Morus alba

Further Reading



www.perennialagriculture.institute

The Perennial Agriculture Institute

- To mitigate climate change by accelerating the adoption of agroforestry and perennial crops. -

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Our new article on perennial staple crops

December 4, 2020

toensmeier

Edit

PAI is happy to announce that our newest article, "[Perennial staple crops: Yields, distribution, and nutrition in the global food system](#)" was published today in *Frontiers in Sustainable Food Systems*. Building on the information presented in PAI Director Eric Toensmeier's book *The Carbon Farming Solution*, this peer-reviewed article by lead author Maayan Kreitzman provides, for the first time ever, peer-reviewed analysis of the yields, nutrition, carbon sequestration, and adoption potential of this important class of perennial crops.

