Chapter 6

Beyond Turf and Lawn: Poaceae in This Age of Climate Change

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Additional information is available at the end of the chapter

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Abstract

Grassland ecosystems dominated by Poaceae are estimated to cover 40.5% of Earth's land base, and domestication of a few edible grass species into highly productive cereal grains aided the shift from nomadic food gathering to field cultivation and higher density habitation. In the Northern Hemisphere, grasses are used ornamentally and for pasture, fodder and forage with little thought that the grasses livestock grazed upon, or those we gaze upon have multi-functional uses elsewhere. In this age of climate change, the use of Poaceae solely for aesthetics and amenity depletes finite potable water supplies that are needed for human survival. Agricultural land is consumed for turf seed production, and land is removed from food production. Cereals and their growing regions, which we have depended upon as food for millennia, are unlikely to adapt to climate change, and this will result in food insecurity and famines. Despite traditional uses of Poaceae in various cultures, many unrealized needs for food, medicine and other material goods could be met elsewhere with knowledge transfer. Our modern relationship with grass as an ornamental or amenity must end. As designers, gardeners and urban dwellers, we must use Poaceae for its multi-functions, which will lead to resilience and survival.

Keywords: Poaceae, grass, lawn, aesthetics, food, medicine, technology, TEK, resilience, invasive, food security, climate change

1. Introduction

During the entire time that humans have existed on this planet, people have been central to landscape changes in most places—from small individual gestures to large collective efforts. Grassland ecosystems dominated by Poaceae are estimated to cover 40.5% of the land area of Earth, excluding Greenland and Antarctica [1]. Grasses though are found in Greenland [2], and more tenuously in Antarctica, where unintentionally introduced *Poa annua* L. has survived for more than a decade near a research station [3].

Grassland ecosystems and their soils gave rise to the coevolution of humans and edible grasses through hand selection and improvement of grains for food and beverages including rice, wheat, barley, corn, rye and oats [4, 5]. Dormant winter seasons in Northern Europe and the domestication of livestock led to the need and selection of superior grasses for hay, fodder and straw bedding [6, 7]. Other grasses proved useful for technology: fuel, shelter, clothing, rope, baskets and various domestic products.

The transformation from wild grain to domesticated cereal helped create high density places of human habitation, and humans require food, energy, water and wealth. Wealth gave rise to the use of grasses for aesthetics and recreation or leisure pursuits ranging from cosmetic lawn and ornamental gardening to turf for golf, lawn bowling, croquet and various other field sports. Until recently, human beings have generally had a free hand in shaping nature to fit our lifestyles. Humans have converted some 30% of the planet (about 3.8 billion hectares) to resource extraction, agriculture, urban and suburban uses. For example, turf grass and lawn coverage of the American landscape, while highly fragmented, was estimated at 164,000 km^2, which it is suggested, represents '*the single largest irrigated 'crop' in the US, occupying a total area three times larger than the surface of irrigated corn*' [8, p 3].

Conversion to lawn and turf in the US, based on urbanization rates, is increasing at an annual rate of 8000 km^2 [9], and these numbers do not take into account the agricultural areas required to produce grass seed to create lawns. The human desire for green, beautiful lawn requires considerable inputs that result in the use of scarce potable water, fertilizers that pollute potable water, and mowing produces greenhouse gases contributing to higher temperatures. Consequently, we now find ourselves facing planetary climate change that is not particularly human-friendly. In the urbanized world, the moment is long overdue where we need to think whether grass and lawn are an essential need, or just a need that follows long-established social norms, without questioning the impacts or necessity.

The planet is confronting dramatic changes in demographics, population growth and increasing frequency of severe climate impacts and natural disasters [10]. Planning and designing for resilience—environmental-social-economic—is the only way to help humans (mostly dwelling in cities) survive, adapt, grow and thrive as these changes affect demands on the built environment, infrastructure, transportation systems, and water and energy resources.

Basic to our actions are the concepts of human (social) adaptation, local and traditional knowledge, environmental values, place attachments and cultural landscapes. The entry point to action is understanding nature (including human nature), and what role it has in placing limits on, or even directing, our actions and efforts to adapt and become more resilient as humans. In the most developed countries, resilience means rejecting purely cosmetic grass use and embracing Poaceae for its traditional technologies within the urban aesthetic, exploring the domestication (or understanding the wild harvesting potential) of other species of Poaceae to adapt cultivation to meet changes in climate such as warmer temperatures, or the new normal of climate extremes.

As I describe in this paper, humans have barely touched the potential of Poaceae to meet their needs for food, medicine, and other cultural and material goods. Cereal qualities and traits were bred and selected to meet specific regional climate realities such as warm season, cool season, short day-length, flooding, higher yields, drought and pests, or disease tolerance. Unless the cultivar or species is locally adapted to changing climate, finding new species, landraces and cultivars that are suitable and will thrive in shifting weather patterns is urgent, to avoid food insecurity and famine at the worst [11, 12].

1.1. Poaceae and climate change

'*Vulnerability hotspots*', are described as regions likely to experience both a decline in adaptive capacity for wheat and maize, and a decline in available soil moisture [13, p. 195]. The regions with lowest adaptive capacity were identified as wheat production areas in western Russia, northern India, southeastern South America and southeastern Africa. Wheat regions most likely to be exposed to drought and lacking adaptive capacity were identified as southeastern USA, southeastern South America, the northeastern Mediterranean and parts of central Asia. For maize (corn), regions with the lowest adaptive capacity include the northeastern USA, southeastern South America, southeastern Africa and central to northern India; when drought is added to the maize model vulnerability hotspots identified include southeastern South America, parts of southern Africa and the northeastern Mediterranean. The future of these cereals as a reliable source of food in these regions, when greater yields and food security are imperative to feed growing populations planet-wide, is doubtful.

The effects of climate change on food production were modelled in West Africa, and a wide variety of adaptation options available were reviewed to ensure immediate and long-term food security, including selecting different cultivars and crop types, more inputs (water and fertilizer), water harvesting during rainy seasons for irrigation during dry periods, and zero-tillage [14, 15]. The adaptation option most likely to be successful under current climate conditions is to develop seeds with '*increased thermal resilience during grain formation*' [14, p. 304), which they note may sustain crop yields under present climate realities, but may not be the best adaptation option for future climate changes. This is the hallmark of a wicked problem [16], as characterized in **Table 1** [17].

1. You don't understand the problem until you have developed a solution; it's cumulative, cascading, synergistic and evolving as it is explored.
2. There is no stopping rule; no definitive problem = no definitive solution.
3. Solutions are not right or wrong, true-or-false, good-or-bad but rather are better/worse, good enough/not good enough.
4. Each wicked problem is essentially unique and novel.
5. Every solution to a wicked is a 'one-shot operation'; it can't be replicated with the same outcomes for any other wicked problem.
6. There is no given alternative solution; potential solutions may be crafted, but more may not have been thought of, and more will be through shared knowledge and understanding.

Table 1. Six characteristics of wicked problems.

1.2. Human adaptation and resilience to changing climate

Rather than dwell on whether an unsolvable wicked problem with potentially dire outcomes for West Africa has been described [14], it seems prudent to recognize that it may be wicked and that there will be parallel scenarios playing out elsewhere on this planet sharing the consequences of climate change. We know problems can't be solved without trying solutions, most often at great cost, including loss of life from famine. In the case of food security and climate change in vulnerable regions, good enough/not good enough strategies still leave too much uncertainty in both farm fields and dinner bowls.

Meanwhile, the privileged developed world needs to re-assess their relationship with grass simply as garden bling or amenity, and learn to associate grass with edible cereals, multi-functionality and survival. There is, for example, an urgent need to reduce and transition from turf seed production, the majority of which is produced in Oregon, to growing sufficient and locally specific climate-adapted cereals [18]. This would remove the burden of, for example, the US importing cereal products from climate-vulnerable countries, while reducing pressure on its own low climate-adaptive southeastern region, which will become an unreliable source of wheat in extreme drought episodes. Despite the US being a major wheat exporter, *Farming Monthly National* [19] reported the export of 63,000 metric tonnes of feed wheat, that is, wheat to feed livestock, from the UK to the US in 2016.

In forecasting shifting climate scenarios to 2070, it was found that Poaceae as a family is unlikely to adapt through climate niche change and migration to more amenable habitat [20]. This is particularly troublesome given that maize, rice and wheat are not only the major plants cropped globally, they currently account for 89% of all cereal production, and supplied 42% of all the calories consumed by humans in 2009 [21]. Instead, seed saving and banking of land-races and non-domesticated species, combined with assisted migration that mimics natural range expansion to safe sites, may become an active management strategy to protect biodiversity, and the food potential of species for the future [22]. It appears crucial to the search for more robust species from the wild to avoid the genetic bottlenecks that occurred through polyploidization events in the domestication of wheat [23]. Before the selection of a few species that led to complete domestication, experimentation with multiple grass species occurred in multiple places across the Fertile Crescent region for centuries [24]. Even then, at the end of the day, looking for new grasses with the potential to replace the staple grains of the past 20,000 plus years may be an exercise in futility (or another wicked problem), if the survival of all Poaceae in these times of climate change is threatened [20].

The challenge is further exacerbated by the conversion of global grassland ecosystems to other land uses, resulting in their degradation, and loss to urbanization [25]. Examples from dry grassland ecosystems on various continents provide a somewhat daunting perspective on the magnitude of effort required to repair landscapes needed for various ecosystem services, including food production [26]. And for additional insight regarding scale, over a period of 12 years more than 500,000 kg of seed from around 250 species was harvested to restore 90 km^2 of Minnesota tallgrass prairie, and that a typical year in which 1000 hectares were replanted '*required roughly 13,000 kg of seed, approximately 5% (640 kg) of which was hand collected*' [27, p. 3075].

Resilience then, in this age of climate change, means that if plants cannot adapt fast enough, humans have to step up and adapt their behaviours, personally and collectively. Every food security issue must be addressed globally, as is the United Nations in attempting to mitigate the present Sudan Famine crisis which has displaced 1.6 million people from East Africa [28]. All resilience and survival efforts must be multi-directional, multi-pronged, shared and collaborative, to simultaneously explore multiple solutions that might fit multiple scenarios, rather than locking in to one expensive alternative that may not eventually work in one region, but may show promise in another.

And so, in juxtaposing the use of grasses solely for ornamental or aesthetic values with famine and food insecurity, it is clear that the moral imperative must yield to seeking and dedicating land to growing high-yielding cereal grasses first and foremost for their food, medicinal and nutritional values. If by chance such grasses have additional values that might meet aesthetic, social and recreational needs, then all-the-better, as in the past, this was commonplace as documented for one area of the Mediterranean [29], or in the cottage gardens that evolved in Britain.

2. Historical perspective on Poaceae as food

> *Certain cereals and pulses (legumes) were domesticated in very ancient times. In about 8000 BC in the Fertile Crescent of the Near and Middle East (present-day Syria, Iran, Iraq, Turkey, Jordan, Israel), wheats, barley, lentil, pea, bitter vetch, chickpea, and possibly faba bean, were brought into cultivation by the Neolithic people. These crops spread from the point of origin. Archaeological evidence indicates that the wheats, and some of the legumes, had reached Greece by 6000 BC and evidence of their presence within that millennium has been found in the Danube Basin, the Nile valley, and the Indian subcontinent (Pakistan). Dispersal continued through Europe, the crops reaching Britain and Scandinavia in 4,000-2,000 BC. There was quite a hiatus in this dispersal until the sixteenth and following centuries when, following the exploration and colonization of various countries, wheat species were taken to North and South America, South Africa, Australia, and New Zealand.* [30, p. xxviii]

During the Paleolithic (Stone Age), which began around 2.5 million years BCE and lasted until the global advent of agriculture in various unglaciated places around 10,000 years ago, wild grass seed from many species was gathered from the landscape for food [5, 31]. It has been previously thought that '*seeds and beans were rarely eaten and never in large amounts on a daily basis*' in the Paleolithic [32, p. 75]. Recent archaeology at Paleolithic sites in Southern Italy has now found evidence that by 32,600 BCE, hunter-gatherers were gathering substantial quantities of wild grains, primarily temperate cool climate *Avena* (oat) species, and had devised stone pestle-grinder tools for the conversion of the grain to flour [33].

Around 8000 BCE, the process of selecting best-performing grains led to the domestication of some cereal crops that were cultivated in the Middle East, and then distributed westwards into Africa, and eastwards to South Asia. As glacial ice retreated, domesticated grains moved north into Europe to replace those wild gathered from around 5500 to 5000 BCE [32, 34]. About the same time that wheats (einkorn [*Triticum monococcum* L.], emmer [*T. dicoccum* Schrank ex Schübl.] and barley [*Hordeum vulgare* L.]) were domesticated, domestication of two other Poaceae, rice (*Oryza sativa* L.) in China and maize (*Zea mays* L.) in Mesoamerica, was also occurring [24]. Although Poaceae is but fifth largest of the plant families, the top four food plants in the world are from Poaceae (in ranked order): sugar cane (*Saccharum officinarum* L.), maize, wheat (*T. aestivum* L.) and rice [35].

While Poaceae currently has around 12,000 species, the majority have never been domesticated, and remain wild [36]. Though undomesticated, the harvesting of wild grass seeds has occurred on all inhabited continents [37], and persists right up to the present day in many parts of the world, even though seed collection and processing can be challenging for various reasons such as widespread distribution patterns with low abundance, shattering, lodging or competition with more dominant species. People turn to gathering wild grass seeds for various reasons—as a basic survival strategy to counter famine, poverty or economic depression, to maintaining traditional agricultural practices, preserving the traditional recreational or cultural activities of gathering of local wild food and plant medicines [29, 38–40], or for ecosystem restoration and biodiversity conservation purposes [41–43].

Of those species domesticated, grasses can be loosely categorized as edible (e.g. cereal grains), medicinal, ornamental, pasture (e.g. fodder and forage), turf (lawn), technological (e.g. biofuel, building, paper, clothing, oils, perfumes and craft materials) and spiritual (e.g. ceremonial smudging and smoking, incense, and other cultural rituals). Some grasses fall into several categories, and some grasses may have a domestic use unique to a single place, while considered as useless elsewhere [44]. Other native grasses domesticated somewhere for food, medicine or technology are dismissed outright as problematic weeds or invasive species somewhere else, with little regard for their rich histories, and traditional uses in their places of origin.

3. Loss of plant utility following translocation of a species

'Plant names often reflect people's belief systems and oral histories' [45, p. 1.171]. For example, quackgrass, originated in Europe and Central Asia, and was introduced to eastern North America by settlers in the eighteenth century [46]. It has since spread and naturalized urban and rural landscapes, been declared a weed in many states and provinces, and is the subject of substantial investments in time, money [47] and research to develop control methods that range from chemical pesticides to organic approaches using cover crops to prevent the spread [48].

Turn to any North American print or web reference on the weedy 'problem' of quackgrass—*Elymus repens* L., (syn. *Agropyron repens* L., *Elytrigia repens* (L.) Desv. ex Nevski), and the various common English names reflect beliefs and opinions about this plant that are relatively unflattering: couchgrass, twitch, quick grass, quitch grass, quitch, dog grass, quackgrass, scutch grass and witchgrass. However, in Lukomir, Bosnia and Herzegovina, for example, it is known as *piriki* [49], which, though used medicinally, translates from Bosnian (and also Croatian), to English as 'wheatgrass' [49]. *Piriki* then is a verbal reminder that this plant has utility as a cereal, albeit a poverty grain, that might be gathered in times of trouble such as the Bosnian War (1992–1995), when cultivating traditional cereal crops was diminished. Along with *vodenica mlini*, locally developed hydro-powered mills in Lukomir are supplied with water from wooden flumes to turn grindstones. When agriculture is practiced, cereal grains such as wheat, oats (*Avena sativa* L.), rye (*Secale sereale* L.), barley and corn are grown for flour.

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In other parts of Europe, quackgrass was considered an important survival food during the First World War when seeds and rhizomes were ground into flour as a substitute for wheat and rye [46], while in Australia the rhizomes are ground sometimes into survival bread flour [50]. Before the First World War, it is reported that the mucilage exuded from quackgrass roots was as effective as glue that the United States imported a quarter-million pounds from Europe annually [51]. While quackgrass is not indigenous to North America, it soon became naturalized and, for example, the plants were used by the Okanagan-Colville peoples as a type of pit cooking container [52], while the White Mountain Apache Tribe of Arizona used quackgrass seeds for food [53]. In Ladakh, a region in Jammu and Kashmir, the northern-most state in India, powdered quackgrass rhizomes are used to traditionally treat irritated bladders and promote urination [54].

4. From quackgrass to quackery and back

Through the twentieth century, as the science of chemistry and modern technology expanded, herbalists were denounced as ‘quacks’ and herbal medicines were replaced by the component chemical compounds synthesized in laboratories and industrial factories [55]. Traditional knowledge has eroded or disappeared, as reported, for example, in Bali [56], or was saved for times of great need to survive famine, war and natural disaster without modern props. The repression and loss of cultural and ecological memory instigated by the colonialization of Indigenous peoples in North America and elsewhere [57, 58] has also turned around and traditional ecological knowledge (TEK) informing herbal medicine is moving from the alternative fringe to a larger arena [59–61].

There is a strong tug between staying local and respecting traditional foods and medicines, and embracing the benefits of globalization through access to new, potentially more tasty or effective products. This dilemma is articulated both from the Eastern perspective, where practitioners of Asian botanical medicine suggest that those working in the West should use Western herbs [62], or whether Eastern traditional use rules apply in the West [63]. In the West (Europe), it is posited that Western herbal medicine in the United Kingdom refers to ‘*using plants largely native to Europe, within a philosophical tradition arising from European thought*’, and to avoid both North American and Eastern plants and healing traditions [64, p. 165].

By the turn of the twenty-first century, this attitude began to turn around as, for example, ‘super bugs’ invading humans have developed antibiotic resistance, and plant pathogens have likewise developed resistance to pesticides [65–68]. Reductionism in modern science is proving to be less helpful in facing new challenges because it compartmentalizes complex topics and ignores TEK, when there is considerable urgency and essentiality in supporting ‘*the integration of methods and results from different approaches and levels of analysis*’ [69, p. 466]. A strong case is made for the integration of evidence-based medicine with TEK in order to avoid reductionism, and understand the plant holistically and ecologically, instead of breaking it down into useable parts and extracts [70]. Preserving TEK has significant positive implications for local socio-ecological resilience, and adaptation to change [71].

4.1. Ethnobotany, traditional use and the search for resilient grasses

The search for plants that have been traditionally used for food, technology and particularly medicine to replace ineffective modern creations has triggered a considerable amount of ethnobotanical field research across the planet. A plethora of research has been published, very recently, and I cite just a few here to provide some scope on the richness of information available for study [72–84]. Make no mistake that some of the studies cited are motivated by economics and profiteering, as the planet is scoured for 'new' plant materials that can become the 'next' food, nutraceutical, medicine or biotechnology product.

The drive to find better-yielding drought or flood-resistant cereals will tread heavily on the territory and cultures of Indigenous peoples. We must avoid the past mistakes of colonial resource exploitation, extraction and expropriation, or as Vandana Shiva says, 'biopiracy' [85]. Biopiracy is commonly seen as misappropriation or theft of plant genetic material—in part, or in whole. However, others speculate whether in the rush to find the 'next new', the motivation could be based on mutual aid and, with prior informed consent, results in knowledge transfer that helps bilateral economic development and conservation of species [86].

Prior informed consent requires the honouring of several UN international conventions. The *Convention on Biodiversity* [87], the *Universal Declaration on Cultural Diversity* [88], and most importantly, the *United Nations Declaration on the Rights of Indigenous Peoples* [89], which set forth global obligations to respect biodiversity and cultural diversity while protecting Indigenous rights to lands and intellectual property. If an outcome of plant exploration is the documentation of TEK, Indigenous peoples reserve their right to share, or not.

With the consent of residents, a study of home gardens in Iberia found TEK and agricultural knowledge to have blended with modern knowledge, resulting in greater social resilience to change [90]. This is attributed to personal changes acquired through learning new knowledge, practices and beliefs. An important point to note is that TEK is not static, but rather grows in response to new knowledge [91]. Rural to urban migration in China has had a negative impact on the environment as modern agriculture supplanted TEK, though through an experimental ecological education programme, the TEK of more ecological agricultural practices was successfully transferred back to the participating agricultural community [91]. Acceptance of TEK and Indigenous low-carbon living is advocated as being the key to climate change adaptation and resilience [92].

Climate change is an evidence-based wicked problem that may be incrementally and cumulatively solvable if we accept that we are all in it together, and admit that ingenuity may come from outside science. This requires solid doses of knowledge intersectionality, and humility, which requires recognizing and responding to ignorance in decision-making [93]. A final point to note is, '*that a specific unit of knowledge is lost or kept by a society is not as important as whether the society retains the ability to generate, transform, transmit, and apply knowledge*', which ultimately strengthens socio-ecological resilience [94, p. 646]. Good advice indeed as I continue this exploration of the changing role of Poaceae in this age of climate change.

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5. The discounting of grass to single purposes and uses

In the 'Western' world particularly, and anywhere else that was exposed to European colonization, 'grass' is a generic term used to describe lawn, turf, sod and pasture. Where did these words originate, what do they really mean and why have they been essentially reduced to single purposes and uses? For the definitions and etymology of the 15 grass-related words shown in **Table 2**, I turned to the *Oxford English Dictionary* (OED) online [95].

Word	Origins	First English use	Definition
Turf	Old English (OE) turf	c725 CE	**1.** Slab pared from the surface of the soil with the grass and herbage growing on it; a sod of grass, with the roots and earth adhering. Also, in early quotations, a small portion of the sward *in situ*. **2.** A sod cut from the turf of an estate, and so on, as a token or symbol of possession.
Grass	OE græs, from Northern Europe	c725 CE	**1.** Herbage in general, the blades or leaves and stalks of which are eaten by horses, cattle, sheep, and so on. Also, in a narrower sense, restricted to the smaller non-cereal Gramineæ [sic], and plants resembling these in general appearance. **2.** The grassy earth, grass-covered ground; esp. ground covered with grass closely mown and rolled, forming a lawn in a public or private garden.
Hay	OE híeg, híg, hég, = Old Saxon houwi	c825 CE	Grass cut or mown, and dried for use as fodder; formerly (as still sometimes) including grass fit for mowing, or preserved for mowing.
Land	OE land	c900 CE	The solid portion of the earth's surface, as opposed to sea, water.
Fodder	OE foddor	c1225 CE	Food for cattle, horses or other animals. Now usually: hay, straw or other dried food used to feed animals, esp. in the winter. Also (U.S. regional): part or all of the corn plant used as animal food. Chaucer (c1390): 'Gras tyme is doon, my fodder is now forage'.
Meadow	OE mædewan	c1275 CE	A piece of land permanently covered with grass to be mown for use as hay; (gen.) a grassy field or other area of grassland, esp. one used for pasture. Also (regional): a tract of low well-watered ground, esp. near a river (cf. water meadow n.).
Pasture	Middle English (ME) pasturre, partly French pastour and Latin pastura	c1300 CE	A piece of grassy land used for or suitable for the grazing of animals, esp. cattle or sheep; pastureland. First as 'Oxpasture', a Yorkshire place-name.

Word	Origins	First English use	Definition
Forage	French fourrage	c1315 CE	Food for horses and cattle; fodder, provender; in early use, esp. dry winter food, as opposed to grass. Now chiefly provender for horses in an army.
Lawn	Old French launde	1340 CE	An open space between woods; a glade = laund, also meaning an open space among woods, a glade.
Herbage	ME before1500 French herbage, earlier 12th C. as 'erbage'	1390 CE	Herbs collectively; herbaceous growth or vegetation; usually applied to grass and other low-growing plants covering a large extent of ground, esp. as used for pasture.
Sod	Middle Dutch, sode, soode, Dutch zode	Before 1475 CE	A piece or slice of earth together with the grass growing on it, usually square or oblong in shape and of moderate thickness, cut out or pared off from the surface of grass land; a turf. Also const. of (grass, turf, etc.).
Swath ǀ Swathe	OE swæþ, swaþu	c1475 CE	The space covered by a sweep of the mower's scythe; the width of grass or corn so cut.
Sward	OE sweard	1610 CE	A piece or slice of earth together with the grass growing on it, usually square or oblong in shape and of moderate thickness, cut out or pared off from the surface of grass land; a turf. To form a sward; to become covered with grassy turf.
Cereal	Latin Cereālis referring to Ceres, the goddess of agriculture	1818	Of or pertaining to corn or edible grain. A name given to those plants of the family Graminaceæ [sic] or grasses which are cultivated for their seed as human food; commonly comprised under the name corn or grain. (Sometimes extended to cultivated leguminous plants.)
Forb	Greek - φορβή fodder, forage (to feed)	1924	An herbaceous plant of a kind other than grass: applied chiefly to any broad-leaved herbs growing naturally on grassland.

Table 2. Words related to grass, extracted from the Oxford English Dictionary online [95].

Old English was spoken between the fifth and twelfth centuries in areas of what is now England and Southern Scotland, and it is from this period that several words related to grass made their appearance. Turf [96] and grass [97] are derived from Old English and make their way into our vocabulary around the same time. However, according to the OED they have never been combined into a single word viz., 'turf-grass' or 'turfgrass', which is commonly encountered in the industry. The second meaning of turf is related to its use in *seisin*, a c1300 feudal term for the conveyance of ownership, which required a witness to observe the physical and literal transfer of a small piece of ground from one person to another. From this meaning, it is easy to see how we talk about personal space in terms of 'my turf', or 'turf wars'.

While today, turf growers and managers would have you believe that turf is just grass or another word for lawn [98], it is clear from the definition that turf has always meant a slice cut from the surface of the land [99], including soil, grass and herbage (other low-growing plants). If only grass is growing in a slice of land, the words to use are sward [100] or sod [101]. Pasture [102] and grass are related to providing food and space for livestock to graze, while fodder [103] and forage [104] refer to swathes [105] of grass cut from meadows, dried and stored for winter feeding of livestock. A meadow [106] is a land permanently covered with grass (and other herbage [107] or forbs [108]) that is protected from grazing most of the year in order to harvest hay [109] to be used as winter fodder. Cereal only entered the lexicon in 1818, as the term for edible grains harvested from various grass species [110].

6. The meaning of lawn

While turf has retracted in meaning, the term lawn has expanded from its earliest connotation in the 1300s to describe an open space between treed woods that may have been used for pasturing livestock. By 1674 CE, the OED [98] indicates a change in definition to '*a stretch of untilled ground; an extent of grass-covered land*' and a hundred years later, lawn again grew to mean, '*a portion of a garden or pleasure-ground, covered with grass, which is kept closely mown*'.

In his monumental *Gardener's Dictionary* [111], Philip Miller, the chief gardener at the Chelsea Physic Garden from 1722 to 1770, expanded on the meaning of lawn, which he described as follows:

> *a great Plain in a Park, or a spacious Plain adjoining to a noble Seat. As to the Dimensions of it, it should be as large as the Ground will permit; but never less, if possible, than thirty or forty Acres. As to the Situation of a Lawn, it will be best in the Front of the House, and to lie open to the neighbouring Country and not pent up with Trees.*

This larger meaning, which Miller expands upon for several pages, certainly coincides with the period-defining works of the English landscape architects Capability Brown (c.1715–1783) and Humphry Repton (1752–1818), who were employed by wealthy landowners to modernize old Medieval gardens and agricultural land into what the designers called 'landscape parks', which would front many country mansions and stately homes throughout Britain, and be admired and then copied elsewhere.

Miller's suggestion that the lawn be located at the front of the house was essentially a visual cue to all who passed by to take notice that the landowner was so rich that they did not need the space for pasturing livestock. Landowners with lawns could afford to do nothing with it except look at it, sit on it and take walks on it, while their livestock was pastured somewhere else on the estate. In another display of landowner wealth, labourers were employed to maintain the large acreages of lawn by hand-scything the grass, with some assistance from pasturing sheep to maintain bucolic aesthetics. Fortuitously, the Industrial Revolution overlapped (c1760–1840), and the 1830 invention of the reel lawn mower pulled by horses, along with subsequent refinements throughout the nineteenth century, gave rise to a push mower that could be used by anyone to maintain a lawn.

Alongside the Industrial Revolution, the many mechanized inventions allowed an agricultural revolution to occur, shifting surplus labourers from farms into city factories, where they could be workers, rise to management or provide specialty trades. Living standards changed, including a rising middle class that had acquired enough wealth to own a city or town home with space for a garden. In the country, farm labourers and rural villagers typically used the area outside their front doors for growing flowers, fruit, herbs and vegetables—the 'cottage garden', which provisioned a household with many necessities. In cities and towns, the working class transferred their cottage garden to allotments. The middle class copied the aristocracy and grew verdant front lawns using improved cultivars of native grasses which required mowing to maintain appearances. Weekly mowing became a ritual. Further inventions created automatic watering devices and the push mower, various hand tools for pulling weeds and by the end of the 1800s, the green, weed-free lawn was ubiquitous

> *Shall it be a lawn of one kind of grass, or of several? Shall it be pure crested dogstail, dwarf and verdant, or shall it be the sheep's fescue of the downs, or shall it be a mixture of pons and fescues and clover? Shall it have yarrow in it, or shall it be severely grass, and grass alone? These are questions which are not to be answered hastily, particularly the yarrow question. They sow yarrow at Kew, but it is true that yarrow is not a grass. But, then, no more is clover. If one could make seven or eight lawns, it might be easier to decide such difficulties.* [112, p. 11]

From the mid-1800s, the front lawn as a measure of success shifted to North America and elsewhere, along with grass-related sports such as golf, lawn tennis and croquet. However, the traditional lawn grasses used in Britain, such as those mentioned in the above quote, were not adapted to the various climates on the North American continent. The US Department of Agriculture searched the globe and by 1897 had determined that Bermuda grass (*Cynodon dactylon L.*) from Africa, bluegrass (*Poa pratensis* L.) and ryegrass (*Lolium perenne* L.) from Europe, several native and non-native fescues (*Festuca* spp.), and creeping bent grass (*Agrostis stolonifera* L.) could be used singly or blended to maintain a robust lawn through the growing season [113]. Rural acreages were converted to the turf and lawn seed industry to meet the growing population's need for grass. By the end of the twentieth century, mown lawns were the dominant expression of urban and suburban landscapes in Europe and North America

> *Consider the many special delights a lawn affords: soft mattress for a creeping baby; worm hatchery for a robin; croquet or badminton court; baseball diamond; restful green perspectives leading the eye to a background of flower beds, shrubs, or hedge; green shadows – 'This lawn, a carpet all alive/With shadows flung from leaves' – as changing and as spellbinding as the waves of the sea, whether flecked with sunlight under trees of light foliage, like elm and locust, or deep, dark, solid shade, moving slowly as the tide, under maple and oak. This carpet!* [114, p. 159]

Lawns are a completely human creation, composed of mono- or poly-cultures of Poaceae, with the occasional inclusion of other forbs and weeds, and are artificially maintained solely for human use [115]. Admittedly, lawns can evoke the feelings in the above quote, but lawns also characterize the globalization of horticulture by ignoring the local—native species, environment and true human needs for resilience in this age of changing climate. As an amenity, lawn and turf grass landscapes consume limited resources such as money, time, water and energy, but even more troubling, they require upkeep that produces side effects such as pesticide run-off into potable water supplies and greenhouse gas emissions into the atmosphere from lawn mower exhaust. Lawns do nothing for urban food production and food security. Concern for the environment and the future of the planet requires recognition that traditional lawns are an unsustainable indulgence that requires a significant re-thinking of open spaces large and small, and then substantial praxis to create a new sustainable urban landscape for the twenty-first century.

The movement towards a new urban landscape began in the 1980s with the quest to find alternatives to grass lawns. This gave rise to many 'how-to' publications [116–120], along with growing interest in local, native approaches to gardening through publications on meadow, grassland and prairie garden creation [121–124]. All these authors advocate for using low-growing and spreading ornamental cultivars and native species to create more naturalistic, sustainable and resilient landscapes that are lower in maintenance, use less water and create habitat. However, the emphasis remained on the aesthetic and ornamental, still often borrowing non-native species from elsewhere in order to make design statements [125–127].

7. Beyond the beautiful: realising the full potential of Poaceae in human resilience

Climate change brings with it benefits and opportunities, including the ability to use plants previously considered not hardy to a region. In 2016, I began testing plants on our newly installed Roof Ecosystem Research Lab that was designed to serve the needs of the Urban Ecosystem programme at Kwantlen Polytechnic University in Langley, BC, Canada (49° 6'33.71"N; 122°38'47.08"W, USDA Climate Zone 8b). On a roof, which receives and absorbs more heat than on the ground, we can test plants at soil temperatures more conducive to lower latitude climates. In doing so, we can gain insight into the potential for new outdoor food crops such as sub-tropical and tropical chilli peppers (*Capsicum* spp.) that were previously unsuitable for outdoor growing because of a shorter season, or cooler and wetter prevailing weather patterns.

One of the plants we grew was lemongrass (*Cymbopogon citratus* (DC.) Stapf.), a tropical perennial native to South and Southeast Asia where it is used as both food [128] and medicine, including antioxidant, anti-fungal, anti-bacterial and anti-inflammatory properties [129]. Lemongrass and its traditional uses have spread throughout the sub-tropical and tropical regions of the world, in part because of its many outstanding medicinal qualities. In most parts of North America, it is hardy in USDA Climate Zones 10 and 11, where it thrives in summer heat. Lemongrass is not frost tolerant and is thus treated in our region as a novelty annual ornamental with spiky leaves, aromatic scent and culinary flavour enhancer anywhere prone to frosts. To achieve perenniality in temperate climates, winter cover is required to protect lemongrass from heavy frosts. While our plants did not survive the killing frosts of 2016–2017, we will be trialling lemongrass again in 2017, and covering with a low poly-hoop house on the roof for overwintering.

In the fall of 2016, a plant materials course taught by the author explored indigenous species from the West Coast of North America, including Poaceae, and their various cultural properties including food, medicine and technology uses. This nascent examination of the properties of Poaceae triggered a search of the university plant database to examine species planted on campus strictly as ornamentals, or labelled as weeds, that are used for food, medicine or technology in their places of origin. I have selected five species from our campus landscape to present as brief case studies, and highlight how little we know about the Poaceae. As designers, horticulturists and gardeners, we must move beyond the ornamental and aesthetic, to understand and embrace the full potential of all plant families to contribute to human resilience from human climate change and the need for food, medicine or different technologies.

7.1. Case study 1: millets, fountaingrass *(Pennisetum spp.)*

Throughout human history, various species of millet have been cultivated for their cereal grains, and a wide variety of millet species is used because '*they tolerate a range of soil types, and have short-weather growing seasons*' [130, pp. 150–151]. Yet, from a horticultural perspective in the Northern Hemisphere, *Pennisetum* spp. are valued solely for their ornamental qualities and the focus on breeding has '*led to improvements such as more intense purple foliage color, disease resistance, and apparent sterility*' [131, p. 525]. While there are five species and numerous cultivars of the genus *Pennisetum* on our university campus, knowledge beyond their use as an ornamental is poorly developed, and sterility might prevent viable seed collection and use.

Purple ornamental millet *(P. glaucum* 'Purple Majesty') is grown for its deep purple leaves that spill from robust stalks and prolific flowers [132]. The cultivar was an All-America Selection Gold Medal winner in 2003 [133]. *P. glaucum* is known in agriculture as pearl millet, and it has been used primarily as a summer grazing and hay crop in the US [134], and incidentally that, '*the cattail-like flower spikes that we left on the plants became covered in tan, feathery seed that small birds such as wrens, finches, and sparrows flocked to*' [133, p. 12]. Habitat attributes aside, pearl millet is highly useful to humans too. The seeds are used raw or cooked like rice, ground into flour, malted, or fermented into beverages such as beer [135, 136].

7.2. Case study 2: cogongrass *(Imperata cylindrica* [L.] Beauv.)

In temperate regions, several cultivars of *I. cylindrica* have been selected for garden use as ornamental plants, including the red-leaved 'Red Baron', also known as Japanese blood grass. As a native species, cogongrass is found in African and Asian grasslands, but has since spread through human dispersal to Micronesia, Australasia, Europe, southeast USA and Mexico. It now has over 100 common names, and is estimated to cover 2,000,000 km^2 (including natural grasslands) of the planet, so much so that it has been ranked in the top 10 worst weeds on the planet by the International Union for the Conservation of Nature [137]. Initially, cogongrass was introduced to new places for soil erosion control on agriculture and reforestation sites. Because it has few environmental limitations, the grass dispersed far beyond human need, or seemingly ability to control. Considerable effort has, and is, being invested into finding management treatments including pesticides and bio-controls that have potential to eradicate it from a variety of ecosystems, for a variety of reasons [138, 139].

Despite the negative aspects of this species, many other uses have been reported including processing the stems for roof thatch, rope and paper-making. As a food, the rhizomes are used to make beer in Malaysia, and in Australia and China the rhizomes are chewed to extract a sweet juice [50]. Throughout Asia, the rhizome has been used in traditional medicine to treat a vast array of ailments, is antibacterial and a diuretic [140]. Recent research indicates that components of cogongrass show promise in the treatment of colorectal cancer [141], and other research has identified root components such as alkaloids and flavonoids [142], and isolated the secondary metabolites [143].

The essential oils of cogongrass are used in Ayurvedic medicine to treat various illnesses [144], and phytotoxic components of the essential oils have also proven effective in the control of other weed species [145]. While cogongrass has great spiritual and medicinal significance to Vedic cultures on the Indian sub-continent, it is suggested that more of the phytotoxic properties should be tested as alternatives to synthetic chemical treatments that result in negative impacts to the environment [146]. Because this plant spreads aggressively by rapidly growing rhizomes, there is potential to derive social value through mechanical management that harvests the roots for processing, rather than using herbicides to kill it outright, and harm the environment.

7.3. Case study 3: maiden grass (*Miscanthus sinensis* Andress)

Miscanthus sinensis was originally introduced to North America from Asia in the 1890s as an ornamental plant, and quickly escaped cultivation and thrived because it produces viable seed, tolerates colder temperatures, has few pests and diseases, and has low demands for water and nutrients [147]. Over 150 cultivars of *M. sinensis* have been introduced [125], of which 40 are generally available to horticulture, and 10 occur on our campus. Traditional uses for *Miscanthus* include roof thatching material and fodder in Japan, where it is known as 'susuki' [148, 149, 150]. It is known as a wild food plant in Korea, where flowers and spikelets are consumed raw [151].

Range expansion scenarios of *Miscanthus* due to climate change indicate that the species will move northwards in North America, Eastern Europe and Scandinavia [152]. *Miscanthus* is considered a weed in Asia, and it was only late in the twentieth century when the genus was evaluated for biofuel potential in Asia [153], following earlier work in Europe [153]. The same qualities that endear this plant as an ornamental have proven favourable for biofuel production.

M. sacchariflorus arrived in the US around the same time as *M. sinensis*, while in Denmark, sometime around 1935 they naturally crossed and formed a triploid (sterile) hybrid known as *M. x giganteus* (Greef and Deuter ex Hodkinson and Renvoize), which can grow to 3+ metres in height [149]. *M. x giganteus* is used in Europe as a commercial energy crop, providing heat and electricity, and ethanol biofuel [154]. The biofuel potential of *Miscanthus* in North America shows much promise as a non-food replacement in the production of ethanol [147, 154], and experimental biofuel production is also occurring in Asia [152]. Marginal lands, often infested with weeds and invasives, could be better managed if used for the production of biofuels such as *Miscanthus*, which, of all Poaceae, is the most productive and possibly the least destructive to the environment [155].

7.4. Case study 4: orchardgrass *(Dactylis glomerata* L.)

Orchardgrass is a tall perennial bunch grass with stiff flat-sided flower/seed heads that resemble a cock's foot, which became its common name in Britain [156]. The plant has coarse foliage which can grow to form dense tufts or tussocks if unimpeded by mowing and grazing. As a cool season species, it is native throughout most of Europe, temperate Asia and northern Africa. It is long established in other temperate regions, and is well adapted to areas with higher rainfall. As such, orchardgrass has long been favoured as a fodder and pasture grass [157], and is a ubiquitous reminder of the agricultural history of a region, long after the land has been converted to other uses.

Besides feeding livestock, orchardgrass has found several human uses. In Poland, orchardgrass is known as 'kupkówka' and the sweet stem base and inner part of young shoots were eaten as a children's snack [158]. In Hungary, it is known as 'ebir', and also eaten as a snack [80]. In south-east Turkey, orchardgrass is called 'ayrik', and after infusing in water, the decoction is consumed to treat rheumatism and urinary inflammations [79].

Nitrate and pesticide contamination of soil and ground water is a serious environmental problem, and finding solutions is the focus of much research. In one study, orchardgrass was the most effective grass tested to remove toxic organic chemicals produced by the leaching of creosote into soil [159]. The *in situ* efficacy of various grasses in remediating soils contaminated with military explosive residues such as TNT found that orchardgrass was most effective at taking up TNT [160]. The versatility of orchardgrass has been demonstrated through successful recovery of nitrogen from the large amount of manure waste applied to pastures by dairies [161].

Along with several other cool-season grasses, orchardgrass was found effective at degrading atrazine in the soil column, and would be a suitable ground layer species for riparian buffer plantings in conventional agricultural areas that are heavily treated with herbicides and other chemicals [162]. Orchardgrass has proven to be a highly useful plant in bio-remediation initiatives to address past environmental mistakes, and this is possibly its highest and best use as we take responsibility for our misuses of ecological goods and services.

7.5. Case study 5: reed canary grass (*Phalaris arundinacea* L.)

Reed canary grass is one of five native *Phalaris* species in North America. It is circumboreal in distribution and native to both North America and Europe where it occurs naturally in wetlands and on the margins of aquatic habitat where there are wet, poorly drained soils [163]. On both continents, it is an important forage grass, which led to the importation of superior seed from Sweden to Canada in the early 1900s [164]. Other cultivars, both agricultural and ornamental, were imported from Asia, and both European and Asian ecotypes have escaped and hybridized with native North American populations. As a consequence, both the escaped cultivars and the hybridized ecotypes exhibit far more aggressive behaviour than the native species, resulting in some confusion over what is native or not, and the listing of reed canary grass as an invasive plant in many US states and Canadian provinces [165, 166].

On our university campus, *P. arundinacea* is the dominant plant species on wet meadows and the unbuilt floodplain areas of a creek that meanders through. Reed canary grass serves as a benchmark by marking the upper edges of flooding and more severe rainstorm effects, which are caused by climate change, and exacerbated by upstream urbanization. Left unmanaged reed canary forms impenetrable 200-cm tall thickets. When rough mown several times a growing season, it functions as a cut meadow, which allows us to carry out riparian ecosystem repair projects that make the floodplain more resilient to flooding. Rather than dwell on whether it is native or not, we hold the species in check by removing the opportunity for seeds to disperse and spread further. At the same time, the rhizomes hold soil in place and prevent erosion. Our management technique has been to leave the cut grass to decay and add organic matter where it drops, which, as you will see in the subsequent text, may be wasteful.

Finding cultural and economic uses for plants such as reed canary grass is perhaps the most ecologically sensitive approach to managing invasiveness. Ecotypes of reed canary grass that are translocated to suitable habitat in other regions behave far more aggressively than the native ecotype [167, 168], and reed canary runs rampant and out-competes other species in the native ecosystem [169].

In First Nations plant technology in British Columbia, reed canary grass is traditionally used in weaving, and the harvest of materials was sustainable, allowing the plants to be judiciously managed without depleting the resource [170]. By harvesting while the plants are still green and growing in late-spring, the reed canary grass can be managed through the removal of flowering parts. The process involves several steps, timed to the seasons:

> *The Upper Sto:lo of the Fraser River, the Lowe Stl'atl'imx and probably other Salish groups imbricated coiled cedar-root baskets with the stout, smooth stems of Reed Canary Grass. They gathered pliable, green stems in May and early June, around the time when wild roses bloom, cut them into even lengths and soaked them in boiling water, then dried them in the sun for several days to bleach them white. They split the dried stems, soaked them, and used them, …., to superimpose white patterns on the weave of split-root baskets.* [171, p. 119]

By contrast, from the world of new technology, the potential use of reed canary grass as a short fibre material found that is more sustainable than the typical trees used in the pulp and paper industry [172]. In Finell's research, a delayed-harvest technique holds the harvest as late as possible until the biomass is completely dry, which may be as late as the following spring after snow-melt, but before new growth begins. The reason for this delay is that '*for fibre production, the delayed harvest gives higher pulp yield, less variation, and stronger fibres*' [172, pp. 19–20]. In drier interior climates, this technique would work; however, in rainy coastal climates, biomass decay is more likely, requiring a fall harvest.

In other cultures, reed canary grass has long been recognized for its medicinal properties, most notably as a psychoactive drug from ancient Greece when Dioscorides reported that *P. arundinacea* was crushed and mixed with water or wine to treat bladder diseases [173]. The natural hallucinogenic alkaloids dimethyl-tryptamine and 5-methoxy-dimethyltryptamine (DMT) can be extracted from reed canary grass [174], and while toxic to livestock, DMT has medical benefits to humans [175].

It has been pointed out that the Internet has made it possible for anyone to find information on growing, harvesting and processing medicinal plants such as reed canary grass for use as a hallucinogen [176]. Humans have a long historical and cultural relationship with the use of hallucinogenic plants to alter the spirit, mind and body [173]. The harvesting of reed canary grass for any cultural or technological purpose would help manage and diminish its aggressive invasiveness in sensitive ecosystems. Natural area managers should look to intersectional collaborations between the scientific approach, TEK and high-tech to address invasive grasses such as reed canary grass, which currently are tagged as wicked problems.

8. Concluding remarks

In Indigenous cultures throughout northern North America (US and Canada), native grasses are gathered for medicine, clothing, domestic products, technology uses and fuel. Of the nearly 900 native grasses found in North America north of Mexico [163], only two native genera in the Poaceae have been domesticated for food, wild rice (*Zizania* spp.) and maize (Zea mays) was domesticated about 7000 years ago from a wild ancestor (*Zea mexicana* (Schrad.) Kuntze), commonly called teosinte [177]. Traditional knowledge of plants and their uses has always been transferred from generation to generation through everyday life activities [178, 179].

As the world grows in population and becomes increasingly urbanized, the connection to Poaceae as a source of food, medicine and other uses is diminished, as is TEK transfer. The need to find cereals more resilient to climate change is increasing in order to feed growing populations and avoid famine. Grasses have been moved around the planet intentionally (for cereal production, pasture, forage, turf and lawn) and over 400 introduced grass species have been recorded in the US and Canada [163]. Many are deemed to be invasive or weedy species, yet they have adapted to their new environment, and in some cases, thrive better than in their native habitat. As I have described in the case studies, many grasses used for ornamental or agricultural purposes, or are declared weeds, have great human utility in their native regions that is poorly understood, if at all in their new locations.

Recognizing the utility of all Poaceae—for food, medicine, fuel—as we know from TEK, traditional science, and the historical record must become a priority for those using grass in urban design, whether for sports turf, front lawns or ornamental plantings. And lastly, humans need to determine whether their survival is dependent on grasses devoted to sports turf, front lawns or ornamental plantings, or whether those spaces should be used, for example, to cultivate edible and medicinal grasses, while the residues are converted to biofuel.

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