

# **Priorities for Turfgrass Management and Education to Enhance Urban Sustainability Worldwide**

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Turfgrasses are unique crop plants in how they grow, how they are managed, how they are used, and what people expect from them. Although citizens often are not aware of their role, turfgrasses are very important to the sustainability and quality of life in urban areas throughout the world. While often misunderstood, people come in contact with turfgrasses constantly, providing recreational opportunities and cultural benefits including creating improved physical and mental health. As living plant systems, they protect soils and influence beneficial modifications to urban climates. Although turfgrasses are highly adaptable and do not require levels of inputs many people believe, management of these turfgrass areas, particularly intensively used recreational turf is becoming more demanding with increased use and reduced resources available. In order to meet those needs, extensive knowledge in a number of disciplines is needed as well as communication skills. In addition, education needs to focus on systems, often beyond the locality, and balance economic, social, and environmental necessities. Examples of decision points in achieving this balance are provided. While challenging, addressing sustainability in turfgrass areas will improve the locations and the urban areas themselves. Education of managers to understand this balance is most challenging in areas where local expertise is not available. This review highlights examples of poor transfer of expertise and then provides three mechanisms being used currently to develop local expertise. Collaboration of local expertise with outside experts can benefit both sides.

**Key words:** turfgrass, sustainability, education, interdisciplinary, indigenous knowledge

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## **Introduction**

The rapid growth of urban areas around the world have resulted in more people living in urban areas than in rural areas (Crane and Kinzig, 2005). This trend will undoubtedly continue for numerous reasons including the often greater availability of employment and income in cities, but also because dense population centers allow for less land to be taken out of food production. Most sustainable development communities include greater density in housing combined with open space for agriculture and/or recreation. In this review article, I wish to focus on the need for recreation and the facilities or plant communities that are uniquely suited to those areas. Those recreation areas

do not provide food or fiber for the population, but instead provide intangible benefits that are often overlooked and undervalued. The most frequently used plant community in these recreation areas is turfgrass, but because these communities are often misunderstood, the inputs needed are often overestimated and then criticized as being unsustainable.

In this review I will introduce what these recreational turfgrass areas are, what they provide to citizens of urban areas, inputs required, and how management of those areas and education of those managing them will need to change. This includes how local expertise can be developed where it currently does not exist. Demands, including increased use, reduced management resources, greater scrutiny of management inputs,

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and poorer quality soils, are becoming increasingly complex therefore agronomic and social aspects must be considered in sustainable turfgrass management.

### Background

Turfgrass serves many diverse functions in urban landscapes and have very different demands and expectations compared to other agricultural crop systems. However, many of these are not well understood, or are not recognized by most agriculturalists. The term “turfgrass” refers to the community of grasses that form a contiguous ground cover that persists under regular mowing and traffic (Beard, 1973; Turgeon, 2008). The term “turf” refers to the grass community plus the surface layer of soil, together with the roots and other below ground plant parts. The plant community may include non-grass plants, such as legumes, sedges, etc., but most turf most is dominated or consists solely of grass species (Turgeon, 2008). While there are literally thousands of grass species worldwide, relatively few are adapted and can tolerate the types of environments and management where turfgrasses are used. The key morphological characteristics of grasses suited to turfgrass use include sub apical meristems, short stems or crown, and lateral growth. Other characteristics include adequate biomass production abiotic stress tolerance

### Unique plants

Turfgrass plants grow differently than many other types of plants and different even than many grasses. Leaf growth is effectively pushed up from below. The growing points of a turfgrass plant are typically at ground level or just above which allows leaves to be cut or removed through mowing, grazing, or wear from traffic, but that removal does not affect the meristem, allowing the plant to continue growing. In addition to the sub-apical growth, stems in turfgrass plants are normally very short and compressed into what typically is termed a crown. This also keeps the growing points of the plant low to the ground. Finally, turf is defined in part by the lateral growth or the mat of roots and plant parts that cover the soil. This lateral growth occurs through rhizomes, stolons, or through tillering. This lateral growth allows the development of a thick and solid turf, but also enables turfgrasses to fill voids in the turf created from wear and constant use and to compete with other plants growing in the plant community.

The most distinctive aspect of maintaining a turf is mowing—keeping the turfgrass short through mechanical cutting or grazing by animals. The frequent mowing or grazing has significant impacts on the plants growth and development due to the reduction in leaf area and therefore photosynthetic potential. This limits root development to some extent and typically reduces the depth. However plants respond to mowing and reduction in leaf area with increasing shoot density to maximize photosynthetic potential. And adaptation to this frequent cutting is nothing short of amazing. Most turf areas are clipped or grazed to approximately 25–100 mm in height, however in sports turf applications, mowing height can be much lower: 12–15 mm in soccer fields and golf course tees and fairways to as low as 2–3 mm on golf course putting greens.

### Benefits

But why do so many people plant turfgrass worldwide? In part a desire to live among turfed landscapes appears to be ancestral and historical. The savannah landscape of Africa could have influenced ancestors to feel most comfortable in settings of grasslands and scattered trees (Falk, 1976). Gardens in Asia dating to 90 B.C.E. have likely included turf, but the typical Western concept of lawns and turf appear to have originated in Europe (Roberts *et al.*, 1992). More important are the functional, environmental, and health reasons for urban turf areas. Many of these are reviewed by Beard & Green (1994) and include protecting soil resources through control of soil erosion and dust, assisting the filtration of water into the ground, trap various pollutants and enhance their degradation, and improve soils by adding organic matter (Qian *et al.*, 2003, 2010; Townsend-Small and Czimczik, 2010) and restoring highly disturbed soils that are common in urban areas.

Urban climate is significantly influenced by turf, such as environmental cooling through transpiration, reduced noise and glare, and increasing the safety of roadsides and high security areas. These and more affects are thoroughly reviewed by Beard & Green (1994). More recently, turf has been associated with many physical and psychological health benefits (Vries *et al.*, 2003; Nielsen and Hansen, 2007). The most obvious is physical health of participants in sporting activities that take place on turf as well as the cushioning it provides for those activities (Beard & Green, 1994). But less obvious are the mental health and

cultural benefits. More green space means more frequent use by citizens of urban areas (Sullivan *et al.*, 2004). This access to green space, which usually includes turfgrass is associated with healthier children and youth (Liu *et al.*, 2007; Bell *et al.*, 2008), especially in inner-city neighborhoods (Taylor *et al.*, 1998, 2002). Even crime reduction has been associated with urban greenspace. (Kuo and Sullivan, 2001). In a recent monograph (Johnson *et al.*, 2013), many of these benefits to urban citizens (health, recreation, etc.) were considered urban ecosystem services. Not only do these plant communities provide the environmental benefits but cultural and health benefits as well, all of which are usually under estimated and underappreciated. These turfgrass landscapes, and many urban landscapes are places where the plants touch millions of people nearly every day in both physical and social ways. Therefore the distinctive needs of turfgrasses must be included in discussions of sustainable cities.

### Expectation and Environment challenges

In addition to turfgrass plants being unique, the expectations and challenges to growth are very different compared to most agricultural crops. Pest resistance is important, much like other crops, as is abiotic stress tolerance (i.e. drought, salt), but yield or biomass production is not. Product quality traits such as protein quality and neutral detergent fiber and other traits important for forages also are not important. Instead, traits and expectations of a good quality turfgrass stand is measured as visual turfgrass quality which includes aspects of turf color, uniformity of the stand, leaf density, and smoothness as well as functional traits like rigidity of the leaves, elasticity, resiliency, and the ability to recover from traffic (Beard, 1973, Turgeon, 2008). While the importance of these traits is apparent, many of these traits are subjective which makes evaluation and determining the end goal very difficult. In other words, what is good quality for one person may not be good quality for another person.

Potentially larger challenges are environmental conditions in which turfgrasses are expected to not only grow but thrive. Temperatures in urban areas may be higher due to the large amounts of pavement (the urban heat island effect) plus reflection from buildings. Frequent use and traffic puts many stresses on the grasses. In addition, urban soils are often highly disturbed through excavation and building processes

leaving destroyed soil structure, less than ideal soil types, layering of different particle sizes which impede drainage and contamination by organic and inorganic solutes (Brown *et al.*, 2000). Even if soils are relatively undisturbed, existing soils may be far from optimal. Rather than crops being chosen based on suitability of a particular piece of land, or optimal land being sought for production of particular crops, the soil type is rarely considered prior to the development of an area. The specific location within in an urban area is greater importance and the turf management is designed, hopefully, to grow a desirable turf.

One example is Stonebridge Golf Course in West Valley City, Utah, USA. This piece of land was planned for a golf course due to its proximity to the city and as part of a corporate development. Soil conditions are far from optimum with clay soils, limited ability for enhanced drainage, soil salinity levels up to and greater than  $15 \text{ dS m}^{-1}$  and pH greater than 9. Only the most salt-tolerant species can survive in these conditions. The commonly used species in this area can usually only tolerate soil salinity levels up to  $6\text{--}8 \text{ dS/m}^{-1}$ . However, the turfgrass quality and function expectations are not lower than other golf courses. In order to achieve the revenue needed, the course needs to be of high quality. Many other environmental challenges also exist. But the turfgrasses are often highly adaptable and amazingly, talented managers can usually provide the quality and function desired. If existing soils and other conditions are not adequate, many high-use athletic fields and golf course putting greens use constructed profiles with sand rootzones and extensive, and many more technologies when budgets allow.

### Management requirements and tradeoffs

Turfgrasses are highly adaptable and fortunately able to tolerate a wide range of environments and stresses. This is quite the opposite view of many publications in the popular press which argue that turfgrasses need many inputs just to survive. But that is definitely not the case. In fact, some species thought widely to be introduced to North America may be native to the region and have persisted for thousands of years. For relatively low stress environments and low expectation situations, turfgrasses do not require large management inputs to survive and thrive. Occasional mowing, infrequent fertilization ( $<1/\text{yr}$ ), sometimes no fertilization, and if needed due to dry climates, occasional irrigation is usually sufficient to provide a



**Fig. 1.** Relationship of management inputs required (labor, fertilizer, water, pesticides, etc.) and the levels of plant stress, use, and expectations on a turfgrass area.

serviceable turf that provides many of the environmental and cultural benefits. But their ability to tolerate stresses often depends on the amount of management and inputs provided.

In general, areas that have more stress and higher functional and visual expectations require more inputs—more expected equals more that needs to go into the turf (Fig. 1). Those areas that are under high stress, especially stress from frequent or excessive use, management inputs increase dramatically. Those same areas often have the highest levels of expectation. Very few plants can tolerate these types of conditions and therefore choosing better adapted species just isn't possible. Daily mowing, weekly or bimonthly fertilization with a variety of nutrients and nutrient forms, irrigation and pesticides to minimize plant stress, and a myriad of cultural practices such as cultivation, environment modification, smoothing are practiced at least once per week. Management practices are done to maximize the growth potential and often the visual quality of the turfgrass plants. But those levels of inputs in the higher maintenance situations, and areas where inputs are simply over-applied have been the focus of concern, specifically the effects of pollution when pesticides and fertilizers are used gratuitously. Books like 'Silent Spring' have helped make the general population more aware of what effects actions taken on their home lawns and landscapes may have. In fact, inputs of any kind to turfgrass are questioned in many popular press books and articles as well as any

potential for sustainability.

However, the management needed on turfgrass areas to sustain the benefits, or ecosystem services, must consider the diversity of the turfgrass and urban ecosystem. It represents a balance of some services over others (Kareiva *et al.*, 2007). Biodiversity is reduced in turfgrass communities because of the management imposed and the aesthetic and functional demands, yet it maintains many of the ecosystem services of grassland communities (Kareiva *et al.*, 2007). As a result, a complex decision making process is required to balance the use of turfgrass its benefits and functions, and the negative effects of management practices it requires. Determining where that balance is will establish sustainability. In terms of energy use, Busey and Parker (1992) wrote a thorough review on energy requirements in turfgrass management, and viewing turfgrass as a resource rather than a commodity. The energy component is an important part of defining what is sustainable, but is not the only part. As summarized by Kareiva *et al.*, 2007, the balance of some ecosystem services in the urban landscape "will guide human activities to minimize the negative aspects and accentuate the human benefits...". A more durable stewardship would manage trade-offs among ecosystem services so that nature and people simultaneously thrive."

In terms of turfgrass management or agronomics, priorities for sustainability should focus on function of the turf first and aesthetics second. In the US, relatively few species tend to be used for turfgrass areas therefore plants are chosen and then managed to fit a particular function. The Low Input Sustainable Turf (LIST) program proposed to define the function of an area first then select the appropriate species to fit those needs (Diesburg *et al.*, 1997; Watkins *et al.*, 2008). Management decisions were based on inputs available and the quality expected so that function was achieved with the fewest inputs. Turfgrass species have been widely studied in terms of reducing inputs and the list of potential species continues to grow. But unfortunately, most alternative species have share of the market and therefore are more costly and less plant improvement work is being done. These economic realities limit choices currently.

Expectations and management to meet them were studied in a pesticide reduction study on a golf course in New York, USA where three management programs were considered: conventional, integrated pest man-

agement, and biologically based (Rossi and Grant, 2009). Environmental impact was measured using an environmental impact quotient. Interestingly, the management programs had few impacts on golfer satisfaction and only in a few instances (summer stress) did quality and ball roll on the golf course putting greens fall below acceptable in the biologically based management program. Based on this study, the lower-impact management programs were in most cases maintaining the golf course and meeting expectations or functions. However total loss of turf and temporary playing surfaces were not tolerated (Rossi and Grant, 2009).

Reevaluation of plant nutrition needs is beginning to occur. Although not yet part of the scientific literature, consultants are revisiting values usually recommended as minimum soil nutrient levels. These minimums are based on data from soil samples from turfs that were rated as average to good by turf managers. The goal by accumulating data on turf sites and matching to actual soil nutrient levels. identifying minimum levels and in many cases are significantly lower than usually recommended soil levels (Pace, 2012).

But sustainability goes beyond agronomic and environmental impact issues. The United Nations (2008) defines sustainability as a relationship between humans and their environment that promotes resource conservation, economic integrity, and social justice. The United States Code also includes those three essential components and defines sustainable agriculture as an integrated system of plant and animal production that will meet needs for food and fiber, enhance the environment, use nonrenewable resources most efficiently as well as the natural resources that agriculture depends on, ensure economic viability of agricultural production and enhance the quality of life for farmers and all citizens (Definitions, 2011). Unfortunately this definition excludes turfgrasses and other ornamentals since it is not a food or fiber crop. In light of these, a definition for sustainable turfgrass management could be adapted from the R&A, the primary golf organization in Europe and SE Asia, as optimizing the function of turfgrass in urban settings in harmony with the conservation of the natural environment under economically sound and socially responsible management (Johnson *et al.*, 2013).

An example of the need for a holistic approach was described in a report of water conservation in the State of Victoria, Australia. Like the three part definitions

above, environment issues like reducing irrigation water use were important, but also the sports clubs and communities needed to understand the sources of the problems, take ownership, and participate in the solutions (Coverdale, 2007). Likewise, in a study of water conservation at public schools in Utah, USA, water savings were increased when the irrigator, in this case the school custodians, were engaged in the decision processes, educated, and then empowered to make decisions based on their knowledge of the local situations (Kilgren *et al.*, 2010). It's apparent from these definitions and two examples that sustainable turfgrass management must go beyond what inputs are applied to turfgrass areas. The entire system must be considered—the impacts on the local environment, the people maintaining the turf, and those using it. Only by integrating all of these will turfgrass management move towards sustainability (Johnson *et al.*, 2013).

### It takes education

It is apparent that the demands on turfgrass areas will continue to grow and at the same time, inputs available to manage most areas will likely decrease. The various parts of sustainability will need to be key factors in management decision making. Specific management practices are reviewed throughout the turfgrass science literature and many times discussed in terms of sustainability. However, every location, every urban landscape, every turfgrass site is unique in its requirements and therefore their management doesn't lend itself to "cookbook" type ore previously prepared approaches. Instead managers need to fully understand the ecology of the turfgrass communities and sites which requires extensive knowledge in soil science, plant biology, plant pathology and entomology and other areas of science to that problems are thoroughly understood. Communication and management skills are also essential. But most important is creativity and ability to troubleshoot problems and understand impacts of every activity that is done on the turf area.

Obviously, education is essential for all turfgrass managers as well as experience making management plans and responding to real situations. In places such as the North America, Europe, and Australia, extensive education programs exist in the form of one-year certificates, two-year associate degrees, four year bachelor degrees, and graduate degrees in turfgrass science and related disciplines. In addition, Extension pro-

grams run by universities provide both basic education to managers who have not completed traditional programs and provide continuing education for those who have. While not all programs educate from the basis of sustainability, that education usually provides the basic plant and environment knowledge required.

Additional education is provided to professional managers with specific emphasis in sustainability from a number of non-governmental organizations. For example, in the golf turf business, efforts such as the Audubon Cooperative Sanctuary Program, and efforts by the United States Golf Association, the Royal Canadian Golf Association green section and the R&A to educate clubs and municipalities on creating a balance between playing conditions and impacts on the environment. Although golf has typically been on the forefront of these issues, because of their visibility and greater resources, other organizations are providing some similar programs for their industries, such as sports turf, turfgrass producers, and parks urban land management. These different sources of education have truly raised the awareness of sustainability in many parts of the world, its importance, and finally it's practice in the management of golf courses and other urban turfgrass areas.

The situation is more difficult however in areas of the world where golf and turfgrass science is relatively new and turfgrass expertise is not widely available. In a number of countries, turf, primarily on golf courses, has become very important for recreation and tourism, and keeps growing. As a result there is significant pressure for more development, and as a result, its associated impacts (Wheeler & Nauright, 2006). The majority of the developments rely heavily on expertise outside of the country for builders and managers since local expertise is often is not available. While many times that outside expertise provides good recommendations, including those relating to sustainability (Bajracharya & Khan, 2004), they do not and cannot know all of the intricacies of the local environment—both physical and social. As a result, poor decisions have been made.

#### Case studies: seashore paspalum and bermudagrass

Seashore Paspalum (*Paspalum vaginatum* O. Swartz.) is a high quality turfgrass species adapted to subtropical and tropical regions of the world. Most notable is its ability to tolerate and even thrive in saline

soils (Christians, 2011; Carrow and Duncan, 2012) which makes it an appropriate turfgrass where soil salinity limits turfgrass growth for areas using effluent or low quality irrigation water. The species has been the subject of much plant breeding work in the past two decades, large improvements in turfgrass quality, and has been sold widely (Carrow and Duncan, 2012). As a result, the species has been considered the solution for many golf courses and athletic turfs throughout SE Asia and therefore frequently recommended by advisors. In areas of high salinity, seashore paspalum performs well in these regions and is well-adapted (Carrow and Duncan). However in many other locations, seashore paspalum is a high maintenance species requiring significantly more management in terms of nutrition, weed control, and disease control when compared to native grasses, such as manilagrass (*Zoysia matrella* [L.] Merr.) (Xie *et al.*, 2009; R&A, 2011a). Similarly, bermudagrass (*Cynodon dactylon* [L.] Pers.) is widely grown throughout subtropical and tropical regions and frequently specified for golf course and sports turf because of its vigorous growth, adaptability to many turfgrass situations, and high quality. However the species struggles and is often outcompeted by other species in many regions of SE Asia most likely in response to low light levels during the rainy season (Razmjoo *et al.*, 1994; Wiecko, 2000; R&A, 2011b). Native zoysiagrass, particularly *Zoysia matrella*, survives well in the low light conditions of the rainy season, requires much less input in terms of irrigation, fertilizers, and pesticides, has relatively high salt tolerance, and can meet the expectations of high maintenance turf.

These are two examples where local knowledge could have benefitted the process while designing and building the golf courses and other turf areas. In these regions, zoysiagrass is native, would be well understood and recognized by local expertise and well adapted to the climatic and soil conditions in the region. It is native and grows widely through large parts of Asia (Brede & Sun, 1995). Knowing that low maintenance levels would be favored to make the golf course more profitable and would make management easier and reduce potential pollution, *Paspalum* would not have been the choice. With that local knowledge, the better adapted and sustainable zoysiagrass would be established. Specification of the best adapted turfgrass species for turfgrass areas are best done in the design phase of development since changing out

species on a large area of a golf course is not usually an option due to cost. As a result, golf course superintendents and turfgrass managers are left to manage a poorly adapted species resulting in high inputs, possibly higher levels of pollution, less satisfaction among the users of the turf, and ultimately high turnover of the managers. Instead,

### Solutions

Outside expertise can be helpful in boosting turfgrass education and research in regions where it is currently lacking. Herdt (2012) summarizes several practices that are necessary to make these educational efforts successful. First and foremost local conditions and institutional challenges must not be underestimated. In addition, it is necessary to avoid too much emphasis on extending “known technology” to other parts of the world without on-the-ground research and practice that involves its own people and developing local capacity (Herdt, 2012). A balance of providing information and expertise while using local perspectives and knowledge while accommodating differences in cultures and disciplinary views in the host country is necessary (Sillitoe, 2004). The specification of bermudagrass and *Paspalum* for golf courses where they were clearly not the best choices are examples of this local knowledge not being incorporated. Research and practice is necessary since that local capacity must assume the responsibility in making choices. Even then, the balancing of local involvement and conducting needed interdisciplinary research is problematic, complicated by difficulties in cross-cultural communication (Sillitoe, 2004).

One solution is transplanted expertise; scientists and experts from other parts of the world who become resident in areas where education is lacking. An example of this in the turfgrass management field is the Asian Turfgrass Center led by Dr. Micah Woods, a US citizen. Dr. Woods was employed as a superintendent in China, pursued a PhD., and then built a consulting and education center focusing on SE Asia. The center has worked closely with superintendents, companies, and golf groups in Thailand, Vietnam, Japan, China, India, Phillipines, and other countries in the region. Programs initiated by this center have gone far to provide much needed educational opportunities in turfgrass management and sustainability (Roberts, 2012).

Linking with an already established educational program is another method of developing local expertise.

The Michigan State University American-Sino Turfgrass Higher Education Program (ASTEP) program provides students the opportunity to earn a BS degree from both Michigan State University and one of four Chinese universities. Faculty from MSU and the resident Chinese institution provide the teaching in China followed with an internship experience at a US golf course or university research program (Mu & Johnston, 2009). Challenges to this type of program include arrangements for faculty to teach in China and delivering meaningful blocks of information (short classes). But the opportunities are potentially greater including increased student numbers in the US, establishing links to allow future collaboration and learning, plus exposure of those students to new cultures—and giving US students a more global perspective in their field (Mu & Johnston, 2009).

Connections and expertise development can also be developed indirectly through service learning programs involving students and faculty with expertise in a science field (agriculture, turfgrass management, soil science, etc.). A program started by Utah State University has provided English speaking classes in China and Thailand to help students and faculty build their language skills in part to perform better on English proficiency exams. In exchange, US students and faculty gained an immersion experience in the country’s culture and scientific practice (Kjelgren *et al.*, 2012). Those scientific links can then develop into full research and education collaboration. One such link is the cooperation of Utah State University with a new turfgrass management program at the Kasetsart University Kam Phaeng Saen campus and a turfgrass supply company. This collaboration is just beginning but plans to involve curriculum development at KU-KPS, graduate student and faculty training, and finally, research results done by Thai students and professors to address turfgrass management problems in Thailand. Although less formal than the program described above, this service learning program provides flexibility to both the host institution and the US institution in terms of developing a wider range of expertise in the home country rather than one specific discipline.

### Conclusion

Whatever the method of building homegrown expertise in turfgrass management, or other fields for that matter, deep knowledge and curiosity of the public’s needs, local challenges, local opportunities, and inte-

grated plant and soil sciences is needed for sustainable turfgrass management. So to move turfgrass areas towards sustainability, what needs to happen? While suppliers may want customers to believe that using their product is the answer to making a turfgrass area sustainable, there is far more involved. A systems approach is needed including choosing the best adapted species for a particular location (grasses are not alike and one grass won't work everywhere), a basic understanding and questioning of plant requirements, an understanding of what the expectations of the areas are, communication with those users, what goes into the inputs we put into the turfgrass system, and the many relationships. Finally, in areas where local expertise is not currently available, that expertise needs to be and can be fostered. Several non-governmental plant breeding and management organizations described in the review by Herdt (2012) shows how it needs to be done. Scientists from other regions where extensive knowledge is available, work in cooperation with local scientists and practitioners to develop education and research abilities. The goal should be have the foreign expertise work themselves out of a job, but in doing so, create strong scientific collaborators.

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