Chapter

# Introductory Chapter: Milestones in *Grasses and Grassland* Research

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## 1. Introduction

In order to understand the significance of changes that have occurred in *Grasses and Grassland* Research and utilization, a short summary of the state of knowledge is required. The purpose of this chapter will be to briefly describe the milestones in *Grasses and Grassland* Research that have occurred. *Grasses and Grassland* are key links in biological resources. They are the sources of many agricultural productions, livestock systems, and environmental issues with positive and recognized impacts on water quality, biodiversity, and landscapes. However, their acreages have been steadily decreasing for many years.

Otherwise, if the livestock structures trend is accused, there is also the lack of knowledge of technicians about the potential of these areas so sensitive to climatic hazards, unproductive, and difficult to be managed. For example, securing fodder systems in organic ruminants farming remain questionable facing these plagues. *Grassland* would interest such systems by making them productive, stable, input-efficient, and environmentally friendly and guarantee good technological performance. In addition, the complexity of understanding the functioning of *Grassland* covers requires synergetic interdisciplinary skills (phytosociology, agronomy, animal technologies, etc.). Optimizing knowledge of *Grasses and Grassland* at scales of production systems should help conceiving self-sufficient, resilient, and sustainable livestock systems, which would meet society's new expectations.

In order to improve knowledge on these issues, this chapter aims to provide scientists, students, technicians, decision-makers, and other development actors with benchmarks for the diagnosis and management of these resources and ecosystem. Topics which were discussed specifically include properties, synthesis, and some applications of *Grasses and Grassland*. Ultimately, what is the contribution of *Grasses and Grassland* to the sustainable well-being of the living?

A "*Property*" is either (a) an original trait, concept, area of research leading to a significant advance in understanding; or (b) a research review acting as a base for further study and development. A "*Synthesis*" is a physical milestone or the production of a substance by the union of chemical elements, groups, or simpler compounds, or by the degradation of a complex compound (www.merriam-webster.com); while "*Application*" is a use to which *Grasses and Grassland* and components are put.

## 2. Some general points

### 2.1 What is "Grasses and Grassland"?

*Grasses* refers to the monocotyledonous green plant, mostly world widespread, rustic over times and circumstances. The Poaceae family as "real *Grasses*" includes cereals, forages, and fodders plants from pastures and lawns. The concept appeared in the fifteenth century, derived from the root "grow." *Grasses* design the climatic vegetation in large areas of low rainfall.

*Grassland* is a community of herbaceous plants mainly *Grasses*, i.e., a grassy area that last at least several years. It is also a forage crop, mainly composed of *Grasses* and legumes, for grazing or mowing.

About 77% of plant species are *Grasses* on *permanent Grassland* exceeding 80% in the spring and only 65% in the fall; the diversity gradient is between 10 and 40 species [1]. Knowing *Grassland* typology may help build sustainable production systems [2].

Indeed, about 18 types of *Grassland* are distinguished [3, 4]:

a. *Seven types of Grassland* occur based on *duration and composition*: (i) *Temporary Grassland* established on monocropping *Grasses* or fodder legumes, by their association for a short or long duration (i.e., 1–3 years versus 3–10 years); (ii) *Artificial Grassland* mainly sown with fodder legumes for 2–5 years, usually in a crop rotation; (iii) *Permanent Grassland*, long-sown (>10 years) with one or various *Grasses* and legumes species; (iv) *Semi-natural Grassland*, i.e., permanent *Grassland* with native *Grasses*, herbaceous, brush, trees, or groves species; (v) Range as wide areas holding native species that are grazed, fenced, or not; (vi) *Natural Grassland* enriched by native *Grasses* for a long time; (vii) *Multi-species Grassland* includes at least three different species from two different families, which ensure more regular production throughout the year and are more resistant to climatic hazards.

b. *Three types of Grassland defined by the objectives*: (viii) *Grazing meadow*; (ix) *Mixed Grassland* for grazing and mowing; and (x) *Hay meadow* for hay or silage in piles or with wrapping.

c. *Four types of Grassland* rise by *the situation and environment* [5], such as: (xi) *Woodland meadows* as part of a dense and meshed network of hedges, i.e., the hedgerows; (xii) *Wet meadows* rich in biodiversity under moderate grazing, regulating watercourses, preventing flooding, and maintaining habitats in open environments; (xiii) *Dry meadows* of the thermophiles and dry hillsides, with low agronomic value and high floristic richness, shelter threatened species; and (xiv) *Pharmaceutical meadows*, i.e., artificial land planted for both soil enriching and medicinal resources provision for livestock.

d. *Four types of Grassland* highlighted on the *ecosystem production and service system perspective*: (xv) *Agricultural Grassland* essentially *temporary Grassland* with at least two species, for stock building (mainly silage) and green feeding, but also including the most fertile permanent mowed *Grasslands*; (xvi) *Environmental Grassland* belong to *permanent Grassland* grazed by dairy heifers and suckling herds, including *Grasslands* mowed by unfertile environments and used in late mowing for ground-dried hay; (xvii) *Meadows "Close to ecological intensification"* including *permanent Grasslands* both grazed (by suckled herds, heifers, and dairy cows) and mowed for hay. Agricultural results are good in all areas: yield, flexibility, quality; and (xviii) *productive meadows*, which are part of the mono-specific, *temporary grassy*, low-*agricultural meadows*, lacking operational flexibility and energy quality, and used for silage, hay, or pasture.

### 2.2 Some milestones in Grasses and Grassland research

About 60 years of scientific investigations performed in sub-Saharan Africa resulted in a high biodiversity of *Grasses and Grassland*. Previously, 9700 *grass* species with higher biomass production were globally reported. But few are more widely grown to establish *Grassland*. Their adaptation to thermal, mineral, and water stress, resistance to diseases and pests, biomasses and productivities, seed production and nutritional values were studied. Natural and artificial crossings and new genetic techniques improved the species and offer physiological and morphological characteristics including leaves and stems rates, duration of vegetative cycle, sustainability, sexual reproduction, and vegetative and apomictic reproduction. *Grasses* provide raw materials for human and animal nutrition, i.e., food grains and forage. They have reached an advanced stage of development, such in miniaturizing floral pieces and specialization in various environments.

Globally, 150 *Grass* species were well investigated in tropical Africa [6]. This number was completed during the last 30 years (1989–2018). The Laboratory of Applied Ecology of Professor Brice Sinsin from University of Abomey-Calavi (Benin) has described about 100 additional *Grass* species. Two groups of *Grasses* exist based on development cycle duration:

- Annual species grown in rainy season wither and die. Their reproduction requires mature seed, whose formation can be hindered by intense plant exploitation [7].
- Perennial species with roots and lateral buds located at ground level in tropical zone [8], persistent for several consecutive years.

*Grasses* are well defined based on specific biological, agronomic, and nutritional characters (**Figure 1**), with three types of morphology, including:

- Erect *Grasses* showing one single axis with reduced basal branching, no shelf of tillers and dotted distribution of ground cover [3, 4].
- Bunching *Grasses* with tillers in many clumps, spots, beaches, or large areas, reproduced by seed, resisted to drought and burnings throughout leaf sheaths arrangements that protect the buds and mostly well adapted to intertropical zone [3, 4, 9]. The most common are *Andropogon gayanus, Hyparrhenia rufa, Panicum maximum*, and *Pennisetum purpureum*.

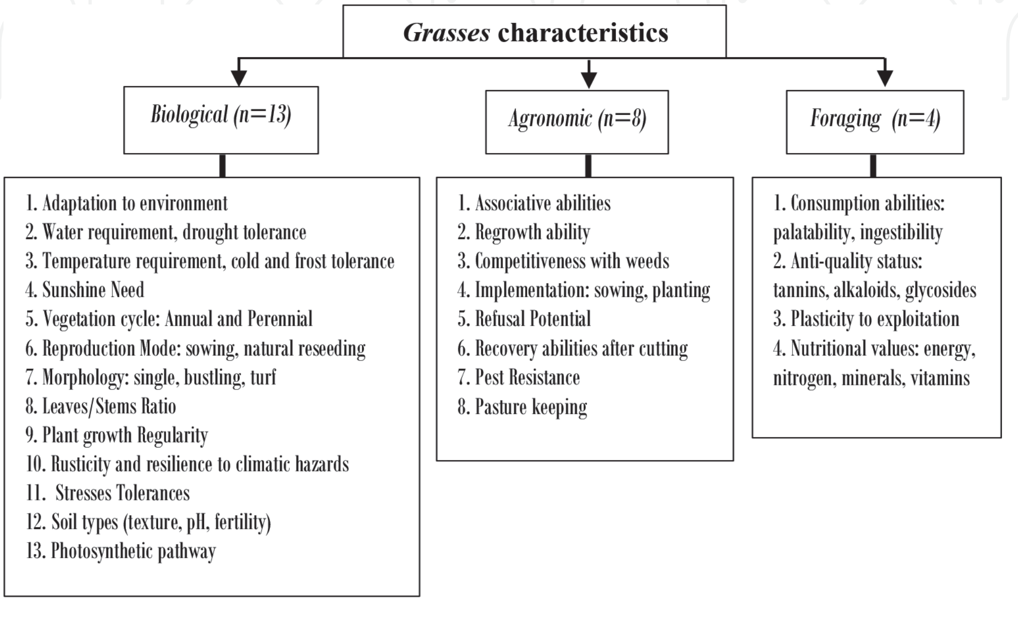


**Figure 1.**
Grasses *main characters (adapted from [10]).*

- Turfed *Grasses* with rhizomes, allowing horizontal colonization. It forms a dense-felted *Grass*, little fire-resistant, producing little viable seed, and propagates by vegetative pathway [3]. They are the main wetland pasture holding mainly *Brachiaria humidicola, Brachiaria mutica,* and *Brachiaria ruziziensis,* which produces many viable seeds, *Cynodon dactylon, Digitaria decumbens*, and *Stenotaphrum secundatum.*

*Grasses*, (i) require light to develop, growing in full sun or little shaded; (ii) colonize open fields with high seed production, regenerative capacity, and soil cover rate; (iii) fast-grow with high leaf-to-shoot ratios. The number of degree days to issue a sheet belongs to discriminative indicators.

Forage *Grasses* palatability reflects tissues soft texture, unobtrusive taste, and odor untainted by unpleasant or repulsive substances, low content of toxic substances (tannins, alkaloids, cyanides, and nitrates), high digestible carbohydrate content, nitrogenous matter, easy abilities to be eaten by tearing on the spot, and their abundance. However, these characters are distributed within the same family. Some species are abandoned while others are overgrazed in the same *Grassland*. Foliar nutritional qualities are low in tropics, less digestible because of higher contents in lignin and fibers, higher refusal rate than in temperate environments (i.e., 10–30% versus 5%).

Tropical *Grasses* differ from temperate at the photosynthesis basic energy metabolism. Tropical have a $C_4$ carbon cycle and Temperate, a $C_3$ cycle. $C_4$ *Grasses* store energy for carbon chains production at night from where they grow faster while *Grasses* at $C_3$ produce carbon chains only in light presence.

These cycles lead to carbohydrates mainly cellulose production. The $C_4$ cycle is efficient in tropics with less nitrogen than in the $C_3$ cycle. Species at $C_4$ optimally develop at higher temperatures than $C_3$ species (between 30 and 40°C versus 20–25°C) with rapid growth, making maximum use in a short growing season. $C_4$ *Grasses* produce two to three times more biomass than $C_3$. Otherwise, they produce more membranes rich in little digestible tissues, with low contents of digestible nitrogen, hence a much less good food value.

Vegetation steps consist of six phases (**Figure 2**).

- *Grasses* can grow in association with other plants based on management practices limiting interspecific competitive effects. Association with legumes offers advantages for soil enrichment in nitrogen mobilized by the legume and

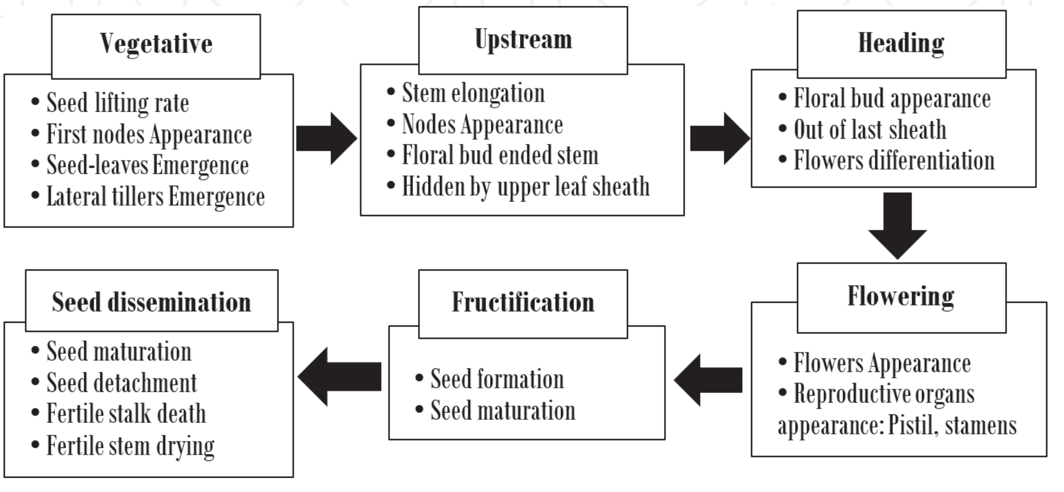


**Figure 2.**
Grasses *phenological phases (adapted from [10]).*

N good absorption from soil by *Grasses* [11]. Rhizobacteria close to some *Grasses* roots allow atmospheric N recovering, a modality less effective than legumes symbiosis.

- *Grasses* have fasciculate roots from the neck, thatch with nodes, and internodes wearing leaves. These form a sheath with elongated blade between sheath and blade, presence of ligule, small and numerous flowers, each wrapped by two lemmas lower and upper made of two opposite pieces, shells protecting the egg (seed), spikelets, or elemental inflorescence units composed of flowers surrounded by a lower and a upper glumes; inflorescences at top of stem, are composed of spikelets grouped into ears, panicles, digested, or geminated.

## 3. *Grasses and Grassland'* traits from research

About 78 parameters are listed as indicators for describing *Grasses and Grassland* (**Table 1**). However, molecular aspects need more attention as well as their warming and adaptive responses.

| No | Indicators | No | Indicators |
|---|---|---|---|
| 1 | Ability to compete with weeds | 40 | Minimum temperature of growth |
| 2 | Ability to spread naturally | 41 | Natural habitat |
| 3 | Ability to zerograzing | 42 | Number of seed per kg |
| 4 | Altitude range | 43 | Nutraceutical properties |
| 5 | Allelopathy properties: phytomolecules and compound released | 44 | Nutritional composition range with climate dependence (proteins, lipids, fibers, ash) |
| 6 | Amino acid contents (lysine, glutamic acid, leucine, alanine, proline, aspartic acid, valine, phenylalanine, serine, isoleucine, arginine, threonine, glycine, tyrosine, histidine, methionine, cysteine, tryptophan, phytosterols, polyconasols) | 45 | Optimum temperature for growth |
| 7 | Animal preference | 46 | Palatability |
| 8 | Animal production | 47 | Pests |
| 9 | Anti-quality elements (Tannins, $SiO_2$) | 48 | Phenolic acids and phenols contents |
| 10 | Bioactive phytochemicals (carbohydrates, proteins, alkaloids, flavonoids, tannins, phenols, saponins, glycosides, steroids, terpenoids) | 49 | Physicochemical characteristics of grains |
| 11 | Chemical analysis and digestibility | 50 | Phytochemicals major families (β-glucan, phenolic acids, flavonoids, lignans, tocols, phytosterols, folate) |
| 12 | Common names | 51 | Pigments or coloring agents |
| 13 | Compatibility with grasses and legumes | 52 | Quality index |
| 14 | Cultivars | 53 | Rainfall requirements |
| 15 | Description | 54 | Refusal rate |
| 16 | Digestibility | 55 | Response to defoliation |
| 17 | Diseases | 56 | Response to fire |
| 18 | Distribution | 57 | Response to photoperiod |

| No | Indicators | No | Indicators |
|---|---|---|---|
| 19 | Dormancy | 58 | Season of growth |
| 20 | DRIS norms, i.e., Diagnosis and Recommendation Integrated System (N/P, N/Ca, N/Zn, K/P, P/Ca, S/P, Zn/P, K/Ca, S/K, K/Zn, S/Zn, Ca/Zn, S/Ca). | 59 | Seed or grain color, shape, size and anatomical elements |
| 21 | Drought tolerance | 60 | Seed production and harvesting |
| 22 | Dry- and green- matter yields | 61 | Seed treatment before planting |
| 23 | Economics | 62 | Seed vigor |
| 24 | Equilibrium moisture of hay | 63 | Seed yield |
| 25 | Fat and fatty acids contents | 64 | Soil requirements |
| 26 | Fertilizer requirements | 65 | Source of variation levels of compounds released and effects |
| 27 | Frost tolerance | 66 | Sowing depth and cover |
| 28 | Further reading | 67 | Sowing methods |
| 29 | Genetics and reproduction | 68 | Sowing time and rate |
| 30 | Grain composition (energy, DM, lipid, fibers, ADF, seed, proteins, ash) | 69 | Suitability for hay and silage |
| 31 | Grazing management | 70 | Therapeutic properties |
| 32 | Growing systems | 71 | Tolerance to flooding |
| 33 | Land preparation for establishment | 72 | Tolerance to herbicides |
| 34 | Latitudinal limits | 73 | Tolerance to salinity |
| 35 | Main attributes | 74 | Toxicity |
| 36 | Main deficiencies | 75 | Value as standover or deferred feed |
| 37 | Maximum temperature, low temperature | 76 | Value for erosion control |
| 38 | Minerals content (K, P, Mg, Fe, Ca, Na, Zn, Cu, Mn, Se) | 77 | Vigor of growth and growth rhythm |
| 39 | Minimum germination and quality required for commercial sale | 78 | Vitamins contents (Niacin, Vita E, alpha tocopherol, Vit BE, pantothenic acid, thianine, riboflavin, folate, fat, fatty acid) |

*Adapted from [3, 6–8, 10–14].*

**Table 1.**
*Alphabetical fields of information on* Grasses *species.*

## 4. *Grasses and Grassland diversity*

### 4.1 Cereals

A cereal is a plant grown mainly for its seeds (grains, fruits, and caryopses) used as food and fodder, being consumed in flour or grain form. "*Cereal*" refers to *Grasses* grains. About 43 cereals from nine main tribes have been documented including 17 Paniceae, 16 Triticeae, 2 Cyperaceae, 2 Oryzoideae, 2 Poeae, 1 Aveneae, 1 Chloridoideae, 1 Coccinea, and 1 Eragrostideae. The most world widely grown are rice, maize, wheat, barley, and sorghum, respectively. Otherwise, about four pseudo-cereals are also worldwide recognized but not yet well scientifically supported: buckwheat (*Fagopyrum esculentum,* Polygonaceae), quinoa (*Chenopodium quinoa,* Chenopodiaceae), amaranth (*Amaranthus* spp., Chenopodiaceae), and sesame (*Sesamum indicum*, Pedaliaceae). Among the several cereals that are used in feeding human over the world, only the high-growth and high-carrying capacity cereals prevent forage shortages in winter. They can also help controlling weeds. Oats are more forage than wheat, barley, rye, and triticale. Potential forage biomass depends on crops, varieties, pathology resistance, and seeding time.

### 4.2 Native Grasses and Grassland

As for Asia, Europe, America, and Australia *Grasses and Grassland*, African landscape offers about six types of wide *Grasses and Grassland*. **Table 2** shows the values, productivities, and demand for equivalent land (i.e., the opposite of carrying capacities) of *Grassland* highlighting the main dominant *Grass* species over the normal periods, i.e., 30 years.

The southern Sahara reflects a dynamic presence of six *Grassland* groups (**Table 2**, [15]) burst into 50 *Grasslands,* including 6 Sudanese, 12 Guineo-Sudanese, 9 Sudano-Guinean, 6 Guinea-Sudanese and Sudano-Guinean transitional, 9 Northern Sudanese, and 8 Sudano-Sahelian. Apart from the most productive *Grasslands*, which are artificial, the most productive native is *Andropogon gayanus* and

| Ecozones | Types of *Grassland* and main *Grasses* species | PV (%) | t DM/ha | ELD (ha/TLU) |
|---|---|---|---|---|
| Sudanese (S) | *Aspilia paludosa* and *Anadelphia afzeliana* (SP1) | 51.5 | 1.08–9.79 | 2.11–0.23 |
| | *Hyparrhenia involucrata* and *Andropogon pseudapricus* (SP2) | 37.3 | 1.21–10.1 | 1.89–0.23 |
| | *Loudetia flavidae* (SP3) | 23.9 | 0.38–5.21 | 6.00–0.44 |
| | *Loxodera ledermanii* (SP4) | 36.8 | 0.30–6.91 | 7.60–0.33 |
| | *Pennisetum unisetum* (SP5) | 46.3 | 0.25–15.76 | 9.13–0.14 |
| | *Setaria longiseta* and *Sporobolus pyramidalis* (SP6) | 21.4 | 0.22–5.58 | 10.37–0.41 |
| Guineo-Sudanese (GS) | *Andropogon chinensis* (GSP1) | 65.82 | 5.00–5.73 | 0.46–0.40 |
| | *Andropogon gayanus* and *Hyparrhenia involucrata* (GSP2) | 74.27 | 5.70–6.86 | 0.40–0.33 |
| | *Andropogon schirensis* (GSP3) | 50.49 | 5.40–7.12 | 0.42–0.32 |
| | *Andropogon tectorum* (GSP4) | 35.04 | 6.06–9.40 | 0.38–0.24 |
| | *Andropogon macrophyllus* (artificial) (GSP5) | 64.40 | 9.73–12.46 | 0.23–0.18 |
| | *Brachiaria ruziziensis* (artificial) (GSP6) | 63.17 | 6.90–9.15 | 0.33–0.25 |
| | *Ctenium newtonii* (GSP7) | 35.04 | 6.33–10.8 | 0.36–0.21 |
| | *Heteropogon contortus* (GSP8) | 35.04 | 6.94–11.4 | 0.33–0.20 |
| | *Hyparrhenia smithiana* (GSP9) | 46.89 | 5.63–7.10 | 0.41–0.32 |
| | *Imperata cylindrica* (GSP10) | 22.82 | 0.29–5.12 | 7.87–0.45 |
| | *Panicum maximum C1* (artificial) (GSP11) | 84.28 | 10.30–13.51 | 0.22–0.17 |
| | *Sporobolus pyramidalis* (GSP12) | 56.02 | 6.53–8.80 | 0.35–0.26 |

| Ecozones | Types of *Grassland* and main *Grasses* species | PV (%) | t DM/ha | ELD (ha/TLU) |
|---|---|---|---|---|
| Sudano-Guinean (SG) | *Andropogon schirensis* and *Andropogon gayanus* (SGP1) | 45.74 | 5.26–8.50 | 0.43–0.27 |
| | *Andropogon schinensis* and *Andropogon chirensis* (SGP2) | 53 | 4.70–8.80 | 0.49–0.26 |
| | *Brachiaria falcifera* (SGP3) | 36.88 | 3.64–7.50 | 0.63–0.30 |
| | *Pennisetum polystachion and Andropogon gayanus* (SGP4) | 28 | 3.93–7.20 | 0.58–0.32 |
| | *Pennisetum polystachion* and *Hyparrhenia involucrata* (SGP5) | 49.33 | 7.86–9.80 | 0.29–0.23 |
| | *Pennisetum unisetum* and *Rottboellia cochinchinensis* (SGP6) | 36 | 3.24–6.80 | 0.70–0.37 |
| | *Sorghastrum bipennatum* and *Schizachyrium sanguineum* (SGP7) | 50 | 4.90–7.90 | 0.47–0.29 |
| | *Sporobolus pyramidalis* and *Hyparrhenia involucrata* (SGP8) | 32.15 | 5.70–8.40 | 0.40–0.27 |
| | *Schizachyrium sanguineum* and *Hyparrhenia rufa* (SGP9) | 45.53 | 4.89–7.01 | 0.47–0.33 |
| Transition Guineo-Sudanese/ Sudano-Guinean (TGS/SG) | *Andropogon schirensis* and *Hyparrhenia subplumosa* (TP1) | 45.8 | 7.01–10.2 | 0.33–0.22 |
| | *Andropogon tectorum* and *Chromolaena odorata* (TP2) | 47.6 | 7.47–10.9 | 0.31–0.21 |
| | *Brachiaria falcifera* (TP3) | 44.8 | 5.57–8.40 | 0.41–0.27 |
| | *Hyptis suaveolens* and *Hyparrhenia suplumosa* (TP4) | 38.2 | 2.03–5.20 | 1.12–0.44 |
| | *Pennisetum polystachion* and *Securinega virosa* (TP5) | 48.15 | 8.25–11.2 | 0.28–0.20 |
| | *Sporobolus pyramidalis* and *Hyparrhenia subplumosa* (TP6) | 33.4 | 7.00–11.4 | 0.33–0.20 |
| Northern Sudanese (NS) | *Andropogon gayanus* (NSP1) | 46.5 | 4.40–6.10 | 0.52–0.37 |
| | *Andropogon gayanus* and *Hyparrhenia involucrata* (NSP2) | 32.71 | 7.53–7.98 | 0.30–0.29 |
| | *Andropogon gayanus* and *Schizachyrium sanguineum* (NSP3) | 52.5 | 4.80–5.02 | 0.48–0.45 |
| | *Andropogon pseudapricus* and *Pennisetum polystachion* (NSP4) | 16.77 | 5.36–5.87 | 0.43–0.39 |
| | *Andropogon pseudapricus* and *Tephrosia pedicellata* (NSP5) | 14.89 | 5.64–5.94 | 0.40–0.38 |
| | *Hyparrhenia involucrata* (NSP6) | 36.2 | 3.95–5.90 | 0.58–0.39 |
| | *Hyparrhenia involucrata* and *Andropogon gayanus* (NSP7) | 38 | 4.80–6.30 | 0.48–0.36 |
| | *Loxodera ledermannii* (NSP8) | 42.69 | 6.58–7.10 | 0.35–0.32 |
| | *Pennisetum pedicellatum* (NSP9) | 23.9 | 2.60–5.50 | 0.88–0.41 |
| Sudano-Sahelian (SS) | *Andropogon pseudapricus* (SSP1) | 26.28 | 2.83–3.21 | 0.81–0.71 |
| | *Andropogon pseudapricus* and *Panicum pansum* (SSP2) | 31.56 | 4.21–5.12 | 0.54–0.45 |
| | *Diheteropogon amplectens* (SSP3) | 28.43 | 3.45–4.10 | 0.66–0.56 |

| Ecozones | Types of *Grassland* and main *Grasses* species | PV (%) | t DM/ha | ELD (ha/TLU) |
|---|---|---|---|---|
| | *Panicum subalbidum* (SSP4) | 31.72 | 3.35–4.08 | 0.68–0.56 |
| | *Pennisetum pedicellatum* of savannahs (SSP5) | 35.06 | 2.42–3.45 | 0.94–0.66 |
| | *Pennisetum pedicellatum* of fallows (SSP6) | 34.05 | 4.12–4.76 | 0.55–0.48 |
| | *Schoenefeldia gracilis* (SSP7) | 14.90 | 3.71–4.01 | 0.61–0.57 |
| | *Vetiveria nigritana* and *Oryza longistaminata* (SSP8) | 41.44 | 6.74–7.24 | 0.34–0.32 |

**Table 2.**
*Types of tropical pastures, grazing values, productivities, carrying capacities (1988–2018).*

*Hyparrhenia involucrata* from Guineo-sudanese and the lowest is *Setaria longiseta* and *Sporobolus pyramidalis* from Sudanese zone.

## 5. Grasses and Grassland properties

### 5.1 Grasses and Grassland food and fodder properties

#### *5.1.1 Native forage grasses*

Temperate wild or permanent and extensive *Grassland* can hold up to 100 plant species per hectare. More than 120 native tropical forage *Grasses* in Africa have been studied and found to less contribute to productivities of respective communities. Special attention has been given to their ecology for better production and rational use [3, 4, 12, 16–19].

#### *5.1.2 Introduced fodder grasses*

The temperate *Grassland* cultivated or more intensive breeding include the following species: Brome (*Bromus secalinus*), Dactyle (*Dactylis glomerata*), *Festulolium* (more than 40 cultivars), High Fescue (*Festuca arundinacea*), Meadow Fescue (*Festuca pratensis*), Meadow Timothy (*Phleum pratense*), meadow Pâturin (*Poa pratensis*), English Ray-grass (*Lolium perenne*), Italian Ray-grass (*Lolium multiflorum* Lam.), Hybrid Ray-grass (*Lolium* × *hybridum*), legumes species such as Cornish lotier (*Lotus corniculatus*), cultivated Luzerne (*Medicago sativa*), cultivated Sainfoin (*Onobrychis viciifolia*), White Clover (*Trifolium repens*), Alexandria Clover (*Trifolium alexandrinum* L.), Micheli Clover (*Trifolium michelianum* Savi.), Hybrid Clover (*Trifolium hybridum*), Incarnate Clover (*Trifolium incarnatum* L.), and Purple Clover (*Trifolium pratense*).

About 30 exotic *Grasses* were introduced from 1987 to 2015 in Southern Sahara, with 17 mainly fodder [7 *Panicum* species (6 varieties of *P. maximum* and *P. coloratum*) and 5 species of *Brachiaria*] [15, 20]. These samples in seagrass beds and on experimental plots are available in the National Institute of Agricultural Research (INRAB), the Faculty of Agronomic Sciences, other research institutions such as ILRI/ILCA (Kenya), FAO (Rome/Italy), CIAT (Colombia), IDESSA (Bouake/Côte d'Ivoire), Democratic Republic of Congo and ILCA (Nigeria).

*Panicum maximum* $C_1$ and *Pennisetum purpureum* are adopted and grown on seedling in density ranging from 30 cm × 30 cm to 40 cm × 40 cm. Several introduced species such as cereals, forage, ornamental and medicinal plants, have already become part of local flora like *Bambusa vulgaris*.

*Grasses* are for several uses: food, fodder, industrial, medicinal, etc. Smaller local cereals are *Digitaria exilis, Oryza glaberrima, Eleusine coracana*, and *Digitaria iburua. Eleusine coracana*, quite recent expansion is mostly grown in mountains. *Digitaria* spp. are famine consumed, mainly *D. exilis* in West Africa, *D. debilis* and *D. iburua* in East Africa (Cameroon). Industrial cereals are rice (*Oryza sativa*) grown in plains and valleys. Wheat (*Triticum aestivum*) is grown on plates in batch production. *Oryza longistaminata* and *O. barthii* are not yet cultivated. *Panicum laetum* and *Cenchrus biflorus* are eaten locally as well as *Brachiaria xantholeuca, Dactyloctenium aegyptium, Echinochloa colona, E. pyramidalis, E. stagnina, Setaria pumila*, and *Sorghum arundinaceum*. Sugar cane (*Saccharum officinarum*) is grown in rural gardens from the south of West Africa (Benin, Cameroon, Sierra Leone, Ghana, Nigeria, Togo, and Guinea) and mainly used for sucking. *Sorghum*, which is not a new crop, is a regional cereal, subjected to large international commercial transactions. It is one of the most important cereals grown especially in arid and semiarid land ecosystems. Holding multiple-use properties, all *Grasses* are browsed by livestock, mostly at juvenile stages and recent is *Grasses and Grassland* developments. *Grassland* improvement by livestock farming and forage stations is based on species such as *Brachiaria ruziziensis*, *Cenchrus ciliaris*, *Panicum* varieties, *Pennisetum clandestinum*, *Pennisetum purpureum*, and *Tripsacum laxum*. *Pennisetum clandestinum* is found on some mountain *Grassland*. *Ischaemum timorense* and *I. indicum* belong to introduced species.

A cultivated forage species is selected based on the following criteria:

1. Ability to produce good seeds, spread by runners, rhizomes, or stem cuttings;

2. Being vigorous, high-yielding, palatable and nutritious, leafy, good foliar quality and late flowering;

3. Resistant under intensive grazing;

4. Ability to survive a dry season, provide pasture for a good part of the dry season;

5. Intended for temporary use, being capable of being eradicated with relative ease.

### *5.1.3 Cereals*

Cereals belong to *Grasses* family. Following are some of their feeding properties:

*A natural fuel*: Cereals hold 70–80% carbohydrates especially starch. They are complex or slow carbohydrates, gradually intestine absorbed, and diffusing energy over time, unlike simple sugars. In its complete form, their shell and fibers slow down this absorption even further. The glycemic index (GI) measures a food ability to increase blood sugar levels within 2 h of ingestion. The higher this GI is, the faster the food is assimilated, and the sooner the feeling of hunger can manifest itself. Whole grains have a low GI, which increases when grains are processed (ground, mixed, blown, extruded … ) because their sugars are then more quickly and easily assimilated.

*Vegetable bricks*: Cereals are *well* provided with protein a little less than meat (7–14%), the richest being wheat and oats). Optimizing them require combination with legumes (chickpeas, lentils, soya … ), one providing each other with the essential amino acid that they lack to cover human needs (cereals are deficient in lysine, well represented in legumes, which are lacking methionine). Hence, traditional associations are corn + red beans in Mexico, rice + lentils in India, wheat semolina + chickpeas in couscous, and rice + peas in Cantonese rice.

*Smooth transit*: Unrefined cereals *are* naturally rich in fibers, which, when indigestible, increases stool volume and promotes stool elimination. These fibers also contribute to satiety through a mechanical effect on the stomach.

*Mineral wealth*: Cereals contain *good* quantities of vitamins of the B group, beneficial for the nervous system, but also vitamin E, antioxidant and many minerals, with mainly magnesium and calcium. **Table 3** highlights some main advantages.

An important cereal food property is Gluten availability. Gluten or prolamin is a protein fraction. Cereals mainly contain it, especially wheat, oat, and barley flour while rice flour is almost exempt from it. Cereals hold sugar (Starch) and protein

| Cereals | Characteristics | Use |
|---|---|---|
| Barley | Low energy and fat<br>Rich in fibers, Vitamin $B_{12}$, Gluten | Interesting for vegans<br>Beaded, crushed, flakes, flour |
| Corn | Sweet taste<br>High glycemic index, energetics | Grains, starch, flakes, flour, syrup<br>Thyroid moderator |
| Millet | Rich in iron, high vitamin A and phosphorus | Anti-asthenic, invigorating, stimulant infection control, cooked, sprouted |
| Oats | Richest in proteins (14.2 g), lipids, Ca, Cu<br>Most energetic<br>Gluten light<br>Digestive, diuretic, tonic, hypoglycemic<br>Lower bad cholesterol<br>Thyroid gland stimulators | Flakes + soy milk, soup, porridge<br>Bread, pancakes, Muesli cakes |
| Rice | Richest in carbohydrates<br>Low in proteins (about 7 g) and lipids<br>Silicon, Vitamins B, fibers | Risottos, pilaf, entremets<br>Flakes, flour |
| Rye | High proteins (about 12 g)<br>Rich in K and B vitamins<br>Less “dirty” than wheat<br>Contains gluten | Bread, whole, crushed, flakes, flour<br>Soft laxative and depurative<br>Blood thinner |
| Spelt (primitive wheat) | 8 essential amino acids<br>11–16% of proteins, high Mg<br>Highly digestible<br>Less gluten than wheat | Hypotoxic diet<br>Anti-stress<br>Sensitive stomach and intestines<br>Flour, soups, cakes, coffee substitute |
| Wheat | Rich in Mg, vitamins B1, PP, E<br>Gliadin | Good for nervous balance<br>Flakes, flour, bread, syrup |

**Table 3.**
*Cereals feeding properties.*

(Gluten). Gluten contains glutellins and prolamins. There are different types of prolamins and glutellins: wheat, for example, is composed of glutenin (glutin side) and gliadin (prolamin side). It is these combined elements that give elasticity to the bread dough and allow the air bubbles to be enclosed. The higher the prolamin content, the higher the leaven on bread. Several cereals are used in feeding human over the world.

*Grasses* contain toxic prolamins such as rye secalin, orange hordein, corn zenin, oat avenin, or wheat prolamin (gliadin), which are well known for toxicity. For this reason, these cereals are generally banned from the diet of people more sensitive to gluten toxicity. All cereal *Grasses* contain gluten (**Table 4**). However, prolamin levels are sometimes so low that prolamin intolerants may consume some of them.

Wheat, Kamut, and Spelt are the richest in gluten while rice contains insignificant amounts, as well as buckwheat. These cereals could perfectly fit intolerant persons as gluten-free flours in shops and supermarkets.

Fonio (*Digitaria exile* and *D. iburua*) as the oldest cereal of ethical minorities in arid sub-Saharan Africa is of nutritional properties as the richest in Mg, Ca, Fe, and Zn, which contributes to properly functioning of the immune system. It is gluten-free and contains twice as many amino acids as other cereals. It can be consumed by coeliac disease victims or wheat allergy, as it contains less protein than others and similar to white rice in composition. No major scientific studies have looked specifically at Fonio. However, being considered as a whole grain, we know about their positive impacts on the risk of cardiovascular disease, type 2 diabetes, constipation, overweight, cancers including colorectal cancer.

### 5.2 Grasses and Grassland anti-erosive properties

Anti-erosive practices favor mounts terraces and foothills covering massifs. Terraces create fields on slopes and among blocks. Millet stalks retain elements from disintegration in place of granite rock slabs of walls sealed with gravel.

| Rank | Cereal | Scientific name | Gluten type (prolamin) | Prolamin content (%) |
|---|---|---|---|---|
| 1 | Wheat | *Triticum aestivum L. subsp. spelta* (L.) Thell. | Alpha gliadin | 69 |
| 2 | Spelt | *Triticum spelta* L. | Alpha gliadin | 69 |
| 3 | Kamut | *Triticum turanicum* D. Love | Alpha gliadin | 69 |
| 4 | Corn | *Zea mays L.* | Zenin | 55 |
| 5 | Sorghum | *Sorghum bicolor* (L.) Moench | Cafirin | 52 |
| 6 | Barley | *Hordeum vulgare L.* | Hordenin | 46–52 |
| 7 | Rye | *Secale cereale L.* | Secalin | 30–50 |
| 8 | Millet | *Pennisetum glaucum* (L.) R.Br. | Panicin | 40 |
| 9 | Oat | *Avena sativa L.* | Avenin | 20–30 |
| 10 | Tef | *Eragrotis abyssinica* (Jacq.) Link | Not identified | 12 |
| 11 | Fonio | *Digitaria exilis* (Kippist) Stapf<br>*Digitaria iburua Stapf* | Not identified | <10 |
| 12 | Rice | *Oryza sativa L.* | Oryznin | 5 |

**Table 4.**
*Classification of food* grasses *according to gluten content.*

| Anti-erosive practices | *Grasses* species used | Organs used | Localities |
|---|---|---|---|
| Terraces | *Adiantum philippense* L. (Ferns)<br>*Cynodon dactylon (L.) Persoon*<br>*Digitaria argillacea* (Hitchcock and Chase)<br>*Rottboellia cochinchinensis* (Lour.) W. Clayton | Stoloniferous roots | Mountains |
| Rock slabs | *Pennisetum typhoides* (Burm.) Stapf. and Hubb. | Stems | Walls |
| Improved fallow lands | *Setaria pumila* (Poir.) Roem. and Schult., 1817<br>*Setaria sphacelata* (Schumach.) Stapf and C.E.Hubb. | Roots, stolons | Uplands |
| Plant defensive systems | *Sorghum caudatum* (Hack.) Stapf.<br>*Sorghum durra* (Forssk.) Trab. | Stems, stolons | Plains and foothills |
| Pseudo-terraces<br>Restored halomorphic floors | *Sorghum caudatum* (Lithosols Sorghums)<br>*Sorghum durra* (Transplanted Sorghums) | Stems | Mountains |
| Bunds gridding | Off- seasoned Sorghums | Stems | Uplands |

**Table 5.**
*Anti-erosive* grasses *(adapted from IRD1995–1996).*

Gradually, these elements rise until an arena beach becomes a field. Bundles of millet stalks and certain *Grasses* (**Table 5**) are arranged to also retain fine elements [21].

Terraces are maintained by particular crops in the blocks interstices, including *Stoloniferous Grasses* such as *Cynodon dactylon* and *Adiantum philipensis,* i.e., a small fern. *Rottboellia cochinchinensis* and *Digitaria argillacea* are cutting and offer 2–3 cuts for cattle feeding in rainy seasons.

Facing foothills and plains land insecurity, new intensive and elaborate anti-erosive practices help to recover hard land (halomorphic soils), which have often been abandoned as a village cattle parking lot. Farmers dig holes 1.5–2 m apart and 35–40 cm in diameter with as much depth in the compacted horizon. They spread all around the manure, fill the holes in the second or third year, and cultivate a first time with the plow, early *sorghum*. Seasoned *sorghums* are grown annually. At this stage, a grid of bunds of 30 cm height is mounted for better water contention. Planting *Setaria pumila* and *Setaria sphacelata* improve fallow lands [22]. Halomorphous soils restoration occurs between 4 and 6 years. In such context, clusters of rocks, as well as halomorphic areas deemed uncultivated, can give fields. The anti-erosive aspect serves essential crops, *Sorghums* of Lithosols Mountain and transplanted *Sorghums*, all of which are free from fallow.

### 5.3 Grasses and Grassland ornamental properties

*Grasses* from wetlands mostly grew for ornamental purposes in dryland irrigation systems (**Table 6**). *Axonopus compressus*, *Cynodon dactylon*, and *Paspalum conjugatum* grew in urban and peri-urban areas, particularly in South Africa (Cape Town, Johannesburg, Pretoria), Benin (Cotonou, Ouidah, Parakou, Porto-Novo), Cameroon (Ngaoundé, Bertoua, Yaounde, Douala), Sierra Leone (Freetown, Njala), Liberia (Monrovia), Senegal (Dakar, Saint Louis, Ziguinchor), Congo (Kisangani, Kinshasa, Brazzaville), Ethiopia (Addis Ababa), Ghana (Cape Coast, Tema, Kumasi, Accra), Nigeria (Abuja, Abeokuta, Shagamu, Idjebu-Ode, Lagos, Ibadan, Ogbomosho, Oyo, Iseyin, Makurdi, Awka, Kaduna, Maiduguri, Yenagoa, Asaba,

| Species | Locations | Utilizations | Ecoregions |
|---|---|---|---|
| *Axonopus compressus* (Sw.) P. Beauv.<br>*Chrysopogon aciculatus* (Retz.) Trin.<br>*Paspalum conjugatum* P.J. Bergius<br>*Vetiveria nigritana* (Benth.) Stapf | Cities bordering African marine Coast | Ornamental, fodder and, medicinal | Tropical wet and dry |
| *Axonopus compressus* (Sw.) P. Beauv.<br>*Cynodon dactylon (L.) Persoon*<br>*Paspalum conjugatum* P.J. Bergius | Cosmopilites | Ornamental, fodder and medicinal | Tropical dry and wet |
| *Chrysopogon aciculatus* (Retz.) Trin. | Airports | — | Cosmopolites |
| *Cymbopogon citratus (D.C) Stapf.* | Home gardens | Ornamental and medicinal | Tropical wet, dry |
| *Oxythenantera abyssinica* A. Rich. Munro | Botanical Gardens, Southern Cities (Wetlands) | Fences and medicinal | Tropical wet, dry<br>Temperate |
| *Phyllostachys aurea Koï* | Gardens of northern cities (drylands) | Fences and handcrafts | Tropical wet and dry |
| *Polytrias diversiflora* (Steud.) Nash<br>*Stenotaphrum secundatum* (Walter) Kuntze | Botanical Gardens | Ornamental and medicinal | Tropical, temperate |

**Table 6.**
*Main ornamental* grasses.

Calabar, Enugu, Akure, Port Harcourt, Bonny, Ahoada, South and North Sokoto, Lafia, Kano, Owerri, Minna, Ilorin, Gombe, Ado Ekiti, Dutse, Katsina, Benin-City, Abakaliki, Lokoja, Osogbo, Jos, Jalingo, Donga, Damaturu and Gusau), Morocco (Casablanca, Tanger, Marrackech, Raba). In addition, two cosmopolitan seal (*Axonopus compressus* and *Paspalum conjugatum*) with *Chrysopogon aciculatus* mark lawns of African, Asian, European, American and Australian coastal cities. *C. aciculatus* outcrops gardens of East and West African airports.

African landscapes are dominated by bamboo (*Phyllostachys aurea*) while those of northern cities (Europe, America, Australia, and Asia) are distinguished by cultivation of *Oxythenantera abyssinica*. *Cymbopogon citratus* is dominant in ornamental and medicinal gardens. *Stenotaphrum secundatum* marks lawns of East African marine coasts, and *Polytrias diversiflora*, Municipal and University botanical gardens. Linear foliage and flowers in form of ears sometimes feathery appear in autumn and bring a graceful and light touch. Near a resting place or water garden, the rustling and swaying of leaves and ears of corn bring into Morpheus' arms. Moreover, *Miscanthus* (*Miscanthus*), Panic (*Panicum*) and *Calamagrostis* (*Calamagrostis*) are other values.

## 5.4 Grasses and Grassland aromatic properties

### *5.4.1 Aromatic properties*

Several aromatic species are grown mostly for oils i.e. lemongrass *Cymbopogon citratus* and *Melinis minutiflora* grown in African gardens (**Table 7**). *Vetiveria*

| Grass species | Aromes | Utilizations | References |
|---|---|---|---|
| *Cymbopogon citratus (D.C) Stapf.* *Cymbopogon densiflorus (Steud.) Stapf* *Cymbopogon schoenanthus* (L.) Spreng., 1815 | Essential oil Citral | Burnt panicles with odoriferous fumes for ceremonials, anti-amoebic, antibacterial, antidiarrheal, antifilarial, antifungal, antioxidants, antimalarial, hypoglycemic, anti-inflammatory, antimutagenicity, antimycobacterial, neurobehaviorial | [23, 24] |
| *Melinis minutiflora* P. Beauv. | Cumin aroma, essential oil | Pesticids, acaricids, ovycids | [25] |
| *Vetiveria zizanoides* (L.) Nash | Essential oil | Tenacious smell, perfumery, cosmetics, strong, pleasant and lasting notes from flavors, insecticides, herbicides, anti-microbial, antioxidant | [26] |
| *Miscanthus spp.* *Miscanthus sacchariflorus* (Maxim.) Franch | Essential oil | Bio-energy, biofuel, bio-crude oil, diesel | [27] |
| *Arundo donax L.* *A. phragmites L.* | Oils, lignin, alkaloids | Biogas, construction, medicinal | [28] |
| *Nardus stricta* L., 1753 *Anthoxantum odoratum* L., 1753 | Coumarins | Medicinal, culinary, cosmetic and economic *properties*, cultivation | [29] |
| *Bromus catharticus* Vahl, 1791 | Aroma | Purgative, spines, burrs, toxics, pest host | [30, 31] |

**Table 7.**
*Some aromatic* grasses*, aromes and usages.*

*zizanioides*, *Cymbopogon schoenanthus* and *C. densiflorus*, cultivated in Cameroon's Adamaoua region, offer essential oils which are widely used in crop protection, storages, veterinary and human medicines.

#### *5.4.2 Grasses and Grassland essential oils composition*

Ninety-five volatile compounds, representing 75.4% of the total area, were identified in essential oils from *Grasses and Grassland* plants, with each of remaining peaks accounting for less than 0.01%. Terpenoid family is mostly abundant with 14 monoterpenes, 24 monoterpene derivatives, 18 sesquiterpenes, and 11 sesquiterpene derivatives, together accounting for 61.1% of total peak area. Besides, were seven benzenic compounds accounting for 12%. Benzenic compounds dill apiole and carvacrol were mostly abundant in essential oil after sesquiterpene germacrene D. The other compounds (1 ketone, 6 aldehydes, 4 alcohols, 3 esters, and 7 alkanes) accounted for 2.3%. Essential oil from *Grasses and Grassland* contained the usual terpenes [32–34].

#### *5.4.3* Grasses and Grassland *medicinal properties*

All organs from *Grasses* are found with specific medicinal virtues for human and animal well-being (**Table 8**).

*Grass seeds* generally exert a particular action on the nervous system, which result in dizziness, and a body tremor as the case for ryegrass and *Festuca*

| Scientific name | Common name | Part used | Dosage form | Medicinal properties | References |
|---|---|---|---|---|---|
| *Andropogon spp* | True lemon grass | Leaf, root, stem | Oil, paste | Anti-arthritic | [35, 36] |
| *Cenchrus ciliaris* L. | Buffel grass | Aerial and root part | Oil | Anti-cancer | [37] |
| *Cymbopogon spp* | Melissa grass, Geranium grass | Leaves | Oil | Anti-amoebic, antibacterial, anticancer, antidiarrheal, anti-filarial, antifungal and anti-inflammatory, antimalarial, anti-mutagenicity, antioxidants, anti-arthritic, anti-mycobacterial, hypoglycemic, neurobehavioral | [24, 38] |
| *Cynodon dactylon* Pers. | Bahama grass | Plant, Rhizome | Extract | Anti-arthritic | [36] |
| *Eleusine indica* Gaertn | Wiregrass | Leaves | Oil | Anti-inflammatory, antioxidants, anti-arthritic | [39] |
| *Imperata cylindrica* (L.) Raeusch. | Thatch grass, Cogon grass | Rhizome, leaves, flowers | Decoction, powder | Diuretic, anti-inflammatory, antioxidant, immunomodulatory, neuroprotective | [40–42] |
| *Lolium temulentum* L. | Darnel | Seed | Powder | Anti-arthritic | [36] |
| *Panicum italicum* L. | Italian millet | Seed | Extract | Anti-arthritic | [35] |
| *Setaria italic* Beauv. | Foxtail millet | Grain | Parching | Anti-arthritic | [35] |
| *Hordeum vulgare* L. | Barley | Grain | Hydroalcoholic extract | Anti-chronic diseases, promote sleep, antidiabetes, enhance immunity, protective liver, beauty anti-acne, antioxidants, antidepressant, anticancer, improve gastrointestinal, anti-inflammation, hypolipidemic, preventive heart diseases, preventive constipation, improve cognition | [43, 44] |
| *Triticum aestivum* L. subsp. *spelta* (L.) Thell. | Wheat grass | Cotyledons, leaves | Extract, juice | Immunoprophylactic, anti-anemia, anti-leukemia, anti-inflammatory, diuretic, antioxidant, laxative, anti-aging anticarcinogenic; astringent, immunomodulatory, phosphorus, antibacterial, anti-venomous, sources of vitamins A and C, calcium, magnesium, potassium | [45, 46] |

**Table 8.**
*Forage* grasses *and cereals specific medicinal properties.*

*quadridentata* seeds in Peru. *Grasses* stems contain sugar before the seeds mature, which gradually disappears. It is especially abundant in sorghum, corn, and optimal only in sugar cane (*Saccharum officinarum*). Fresh sugar cane contains 18% of his sugar weight. However, these odorless stems show aromatic properties in some grasses, such as *Cymbopogon schoenanthus* (sweet rush), *Anthoxanthum odoratum* (sweet rush), *Cymbopogon nardus* (*Ceylon citronella*), and *Cymbopogon citratus* (Citronella and Indian verbena).

Aromatic *Grasses* are known to be responsible for benzoic acid presence and an associated essential oil in herbivores urine. More specifically, *Saccharum fatuum* from Otahiti (French Polynesia) and *Bromus catharticus* from Peru are used to intoxicate fishes.

*Grasses roots* are sometimes used in medicine. Most are odorless, providing only little sugar and gum to the water. Main ones are: *Carex arenaria* (fake sarsaparilla), dogs: *Panicum repens* (Torpedo grass), *Imperata cylindrica* (Spear *grass*), *Cynodon dactylon* (Couch *grass*), and *Arundo donax* (cane root).

Some *Grass* roots are aromatic. This is the case with *Vetiveria odorata*, which contains a resin with a myrrh smell associated with volatile oil. *Vetiveria*' roots from Brazil served as a powerful sudorific.

*Grass seeds* provide a viscous drink in water; this seed decoction contains sugar, and gluten which dissolves with acetic and phosphoric acids. An herbal tea is made by mixing rice seed, oatmeal and barley. This drink contains grape sugar, dextrin, starch and gluten. The cane and quackgrass root are used to prepare soft drinks: quackgrass scales washed in cold water, contoured in a mortar and boiled for a quarter of an hour. Quackgrass (*Imperata cylindrica*) extracts are also obtained by roots leaching. *Grass starch* is used in many preparations to treat some humans and animals' diseases.

### 5.5 *Grasses and Grassland* ecological properties

Evidently, restoring native *Grasses* and *Grassland* is highly desirable. To that end, scientists might build models predicting human disturbance on global *Grassland* and assessing the climate-biosphere feedbacks as light grazing promoted soil C and N sequestration whereas moderate and heavy grazing significantly accelerated C and N losses. Indeed, light grazing also increase the above and belowground biomass, stimulate more fixed C allocated to roots and increase root exudates and biomass [47]. This enhances soil C accumulation as well N inputs into soils [48]. Meanwhile, light grazing also stimulate soil respiration by increasing temperature and moisture, enhancing ground cover, decreasing compaction, stimulating plant growth and microbial activities [49, 50]. However, both moderate and heavy grazing markedly decrease soil carbon pool and soil nitrogen pool as grazing decrease litter biomass, root C pool and microbial biomass and then lower C inputs to soils [51].

Fire remains a major disruption to evolution and management as well as determining *Grasses and Grassland* ecosystems. Fire is known for improving framework and resource environments, i.e., animal and livestock habitat. Prescribed fire is a tool for modern pasture management. Seasonal uses of fires, herbicide and nitrogen applications become promising, as desirable *grass* biomass increases while invasive plant biomass decreases. About three types of fires are mostly used in Tropics [52] for example, i.e. (a) *early fires* applied when the soil moisture degree is still sufficient to produce *grass* regrowth that is highly valued by livestock and covers their forage needs during the dry season. It cleans the straw left on the ground at the end of dry season. Its ignition date coincides with the end of the rainy season (mid-November to end of December, depending on the case). As results, it stimulates the growth of hemicryptophytes, improves primary biomass production of pastoral ecosystems and allows better land cover. (b) *Off-season fires* lit in the middle wet season and depends on: (i) the effort to conserve standing straw used as combustible for fire, (ii) the biomass ratio of "green matter/straw," which must be less than or equal to 1; where perennial *Grasses* abound, prescribed fires provide livestock with tender and palatable forage in a forage-deficit season. (c) *Late fires* applied when the degree of drying is maximum, very violent, compromising the regeneration of forest recruits and chamephytes species often despised by animals. It reduces woody plants density, promotes *Grass* growth, and accelerates bare beaches reducing by the way the pastures' carrying capacity.

But, using fire for sustainable *Grasses and Grassland* require optimal ecological conditions as well as specific well trained staffs.

Some species are important in regards to their roots which were highly used for human and animal medicine. These species (*Andropogon* spp., *Cenchrus* spp., *Cynodon dactylon* and *Imperata cylindrica*) appeared to be highly threatened and thus, their culture should be encouraged in order to make them more available for all needs.

It appears that all the listed *Grasses* are heavily attacked by a multitude of diseases and parasites (**Table 9**). Although efforts have been made to enable each of these plant species to provide the expected yields (productivity, food quality ... ), from another point of view, it is important to highlight their overall major ecological

| ***Grasses*** | **Model species** | **Number diseases** | **Main foliar diseases** | **Economic parasites** | **References** |
|---|---|---|---|---|---|
| Wheat-grasses | *Agropyron* spp. *Hordeum* spp. *Triticum* spp. | 70 | Rusts, smuts, blotches, spots, scald, scolecotrichum stripe, powdery mildew | *Erisyphe graminis* | [53] |
| Needle-grasses | *Stipa* spp. | >50 | Spots (septoria, selenophoma, stem), stagonospora .blotch, stripes | *Scolecotrichum graminis* | [53] |
| Blue-grasses | *Poa* spp. | 50 | Rusts, stripe, spots, powdery mildew, anthracnose, smut, fairy ring, melting-out, silvertop, slime molds | *Laetisaria spp, Entyloma spps, Clitocybe, Lycoperdon, Psalliota, Typhula, mites, Drechslera, Fusarium, Erysiphe graminis* | [53] |
| Smutgrasses dropseeds | *Sporobolus* spp. | 36 | Rusts, spots, powdery mildew, mold, Smut | *Helminihosporium ravenelii* | [54] |
| Grama grasses | *Bouteloua* spp. *Aristida* spp. | 30 | Rust, spots, choke, scald, black ring | *Balansia strangulans, Balansia hemicrypta* | [55] |
| Canary grasses | *Phalaris* spp. | 30 | Tawny spot on leaves | *Pseudomonas coronajaciens* | [53] |
| Brome grasses (Mountain, meadow, smooth) | *Bromus* spp. | 38 | Spots, anthracnose, powdery mildew, mold, scalds, rot, speckle, blotch, stripes, rusts, Smut, Silvertop, Blight, Node | *Pseudomonas, Ustilago bullata, Fusarium, Pyrenophora sp, Selenophoma bromigena, Xanthomonas translucens, Alternaria spp., Claviceps spp, Erysiphe graminis* | [56] |

| *Grasses* | Model species | Number diseases | Main foliar diseases | Economic parasites | References |
|---|---|---|---|---|---|
| Foxtail Millet | *Setaria itálica* | 22 | Spots (Cercospora, helminthosporium, bacterial, gray), downy mildew | *Piricularia grísea, Sclerospora graminicola* | [53] |
| Meadow Foxtail | *Alopecurus pratensis* | 19 | Stripe, water-soaked, blotches, scalds, streak, rust | *Rhynchosporium spp, Drechslera sp., Sclerotinia borealis; Puccinia graminis* | [53, 56] |
| Buffalo grass | *Buchloë dactyloides* | 11 | Spots, false smut | *Cercospota seminalis* | [53] |
| Beardgrass/ Bluestem | *Andropogon* spp. | — | Rusts, choke, anthracnose, cattail, spots | *Phyllachora luteomaculata* | [57] |
| Wild-rye grasses Junegrass | *Elymus* spp. *Koeleria cristata* | 14 | Rusts, smuts, powdery mildew, spots, blight, stripe, speckle | *Epichloe typhina* | [53] |
| Bentgrass | *Agrostis* spp. | 13 | Patchs, molds, spots, leaf blotch, Pythium Blight, red thread | *Rhizoctonia solani, Typhula spp, Coprinus spp, Drechslera, Sclerotinia, Leptosphaeria korrae, Fusarium, Pythium, Laetisaria spp* | [58] |
| Fescue, Red | *Festuca rubra* | 14 | Anthracnose, molds, red thread, silver top, spots, scald, smuts, Brown stripe, blotch, powdery mildew, rust | *Colletotrichum graminicola, Typhula spp, Coprinus spp, Fusarium spp, Clitocybe spp Marasmius spp, Lycoperdon spp, Psalliota* | [59] |
| Timothy grass | *Phleum* spp. | 06 | Spot, blight, rot, mold, ergot, snow scald | *Heterosporium phleum, Drechslerai, Pythium, Claviceps purpurea, Sclerotinia boreali* | [60] |

**Table 9.**
Grasses and Grassland *pressures and extents of diseases.*

interest. Indeed, these species also serve as shelters and refuges or habitats as well as food resources for many of these parasites, i.e., insects, bacteria, fungi, etc. They therefore participate in the development of ecological niches in a context of habitat fragmentation, an overall major role. Therefore, how can we perpetuate the usefulness of *Grasses* in the midst of various plagues and attacks from grasshoppers, striga, cantharids and anthracnose?

Conservation and enhancement for the majority of introduced forage species are aimed at scientific, cultural, and touristic purposes. Herbarium and *ex situ* conservation, i.e., laboratories, are still on a very small scale in Central and West Africa.

Some tropical native *Grasses* deserve special attention such as:

- Fire-sensitive species that, lose fruit-bearing performance. These are therophytes *Grasses*, mainly *Hyparrhenia involucrata* and *Pennisetum polystachion* [61].

- Forage sensitive to trampling, i.e., *Aristida kerstingii*, *Urochloa indica*.
- Rare genera: *Elymandra androphyla, Loxodera ledermannii, Hyperthelia dissoluta*, which require further attention
- Grazing-sensitive including *Hyparrhenia smithiana* and *Pennisetum unisetum* [3, 4, 9], *Setaria sphacelata, Anadelphia afzeliana, Brachiaria falcifera,* and *Loxodera ledermannii,* less silicified under grazing pressure making them more vulnerable [12].
- Site indicator, i.e., *Brachiaria brachylopha* for dry sites and *B. falcifera* for subhumid sites [62].

*Grasses and Grassland* biodiversity conservation requires (i) a comprehensive census to define the biodiversity conservation strategy; (ii) programming and planning to regulate grazing pressure; (iii) updating revision of herbaria; (iv) *in situ* conservation, and (v) wild *Grasses* domestication.

However, a specialist look is requiring for following concerns: (i) Are livestock grazing and burning compatible? (ii) How to reduce invasive species impact on *Grasses and Grassland* facing biodiversity erosion? (iii) What alternatives to issues in temperate environments as well as facing pests' damage extent? (iv) What would be *Grasses and Grassland'* contribution to agricultural and environmental services in a variety of systems that value permanent *Grassland* in the forage system?

### 5.6 *Grasses and Grassland* cultural properties

*Grasses* are important both in everyday life and during mourning ceremonies, links, knot of all kinds (portage, forbidden, calendars, stubble or signs of fallow land ...) [63]. They are surrounded by several spells, superstitions, myths, legends as well as popular beliefs. Among 15 of these properties reported for example on the wheat are the following:

- *Wheat is a tool in religious rites* of ancient Egyptians, Assyrians, Chaldeans, Romans, Greeks, as well as in India. Its bread has become the central mystery of Christianity. As a symbol of food, fertility and the annual rebirth of life, wheat is the offering of the Harvest Day in Luna sad, Ireland (August 1 in the Northern Hemisphere, February 1 in the Southern Hemisphere).
- *Wheat is a symbol of fertility* often used newlyweds' home decoration [64], offering happy inspiration, gratitude, prudence united to goodness, legitimate acquisition [65].
- *Lucky sheaves*: for hares, partridges and farmers because of the Wheat genius which embodies a last sheaf shaped like a wolf.
- *Uncompromising guardians*: Other wheat geniuses such as *Polievik* in Russia or *Polevik* in Poland hunt pests and weeds and promote harvests. But he will strangle those who would take a nap instead of plowing their land! *Poludnica* ensures breaks observance. *Polednice* in Czechoslovakia and Slovakia prevents damage before harvest while *Polednicek* prevents fields from being ransacked.

## 6. *Grasses and Grassland* syntheses

*Grasses* hold a lot of syntheses as about 27 have been partly listed from the main cereals (sorghum, oat, barley, wheat, maize, Spelt). These chemicals and biologicals act as anticancer [37, 66], increasing milk production [67], antifungal, antibacterial [37], anthelmintic, anti-amoebic, cyclooxygenase (COX) I and II inhibitory activity [68], dysmenorrheal and uterine relaxing activities.

Among the *Sorghum* synthesis (**Table 10**), very little is still known on the Dhurrin genetic control. However, Dhurrin content was recently found in consistent association with biosynthetic genes in N-fertilized environments, while with catabolic loci in the controls [78]. Several phenolic compounds also accumulated radioactivity.

Engineering strategies targeting plant biomass lignin develop sustainable bio economy. Tricin native monocots lignin polymer initiate the lignin chains polymerization. Its bio-synthesis requires two methylation reactions involving the pathway intermediate selgin. O-methyltransferase is producing S lignin units as in the lignin-linked tricin synthesis [79].

The 1,3-propanediol is bio-produced from white sorghum starch and glycerol inoculated by a mixture culture of *Escherichia coli* and *Klebsiella* species [80].

Meeting the human nutrition balance needs require improving protein and amino acids relative contents in rice grain.

The use of genetic engineering strategy can improve essential amino acids contents, and nutritional quality of rice grain. But, how to regulate lipid metabolism pathway in rice grains remains questionable.

| Species | Bio-synthesis | Characteristics | References |
|---|---|---|---|
| Sorghum | Dhurrin | • Cyanogenic glucoside in early grain development<br>• Low-juveniles vs. high-older plants contents<br>• Highest in *Caudatum* and lowest in *Guinea*<br>• Shift from leaves to stem | [13] |
| Rice | Amino acid in grains | • Lysine, first limiting amino acid in cereals<br>• Lysine, methionine, threonine and isoleucine | [69] |
| | Aromatic amino-acids | • Increasing tryptophan and phenylalanine rates<br>• Cysteine, serine, methionine change into isoleucine | [70] |
| | Vitamins in grains | • Foliar β-carotenoid synthesize humans vitamin A<br>• Transgenic produce β-carotenoids in endosperm.<br>• Transgenic folic acid as 1.5 times of original<br>• Thiamine/vitamin B1 low in plastids causing beriberi<br>• Vitamin E as tocopherol, trienol family<br>• Vitamin E as anti-oxidative damage protection<br>• Vitamin C as antioxidant, antiatherosclerosis, anti-cancer | [71, 72] |
| Oat | Avenancins as saponins | • Protective properties, i.e. anti-inflammatory, antifungals, anti-bacterial, anti-parasitism, anti-cancers and anti-viral | [73] |
| Wheat | Storage protein | • Prolamin gene stimulation at storage onset | [74] |
| | Gluten | • Gluten proteins heredity by starch gel electrophoresis<br>• No gluten effect on Canthatch variety D genome | [75] |
| | Antioxidants | • Antioxidant by reducing glycoside, polyphenolics | [76] |
| Barley | Starch and amino acid in grains | • Less starch, dry weight in transgenic endosperms | [77] |

**Table 10.**
*Some cereals synthesis.*

Little is known about Vitamin C biosynthesis in monocotyledonous plants. Therefore, solving low vitamin content in rice grains, require increasing vitamin of rice seeds and improving nutritional quality by making rice, full use of its genes. Achieving this might consider the introduction of exogenous genes, metabolic engineering, genetic engineering and other modern technical methods.

## 7. Grasses and Grassland applications

Ecosystem services of *Grasses and Grassland* are expressed through grazing areas, watershed water, biodiversity reserves, tourist sites, recreation areas, religious sites, wild food sources, and natural medicine sources, mainly through the sequestration and storage of C.

Several species of large *Grasses* are also very important for the manufacture of mats and for the roof. Normally, they are protected against fire and grazing, but rarely cultivated. For the manufacture of mats along the Logone, *Hyparrhenia rufa* is planted. *Vetiveria nigritana* is used for the fields' demarcation on floodplains, and anti-erosion. Vetiver's thatch is traditionally used to cover the roofs of straw huts, and to make basketry or carpets. *Bambusa vulgaris* is planted for timber in southern countries while *Oxytenanthera abyssinica* is often more notable in the north.

*Miscanthus* from Asia as well as sweet sorghum (*Sorghum bicolor*) and switch-grass (*Panicum virgatum*) from USA [81] are material for biofuel and buildings. Ciments Calcia and Alkern as Industrial company substitute's traditional aggregates with crushed to reach 60% *Miscanthus* in the concrete; a prototype block of 20 × 50 × 20 cm weighing 17 kg is three times more insulating than conventional concrete [82]. Insulating panels and biomaterial in term of acoustic comfort with noise attenuation, it is 4 h fire resistance. First experimental use of concrete in early 2018 deployed on 1700 $m^2$ of facade of 46 social housing units in Chanteloup-en-Brie (France) requires 50 tons of *Miscanthus*.

These are biosourced materials, grown without pesticides and irrigation, adapts to polluted, degraded or abandoned land, out of competing food agriculture, offering additional resources and economic opportunities for farmers. Production is spread over 15–20 years without reseeding or fertilizing. In addition, *Miscanthus* is sterile, rhizome and non-invasive, yielding 10 tons/ha per year. It reduces the building's carbon footprint by saving on the transport of aggregates over long distances.

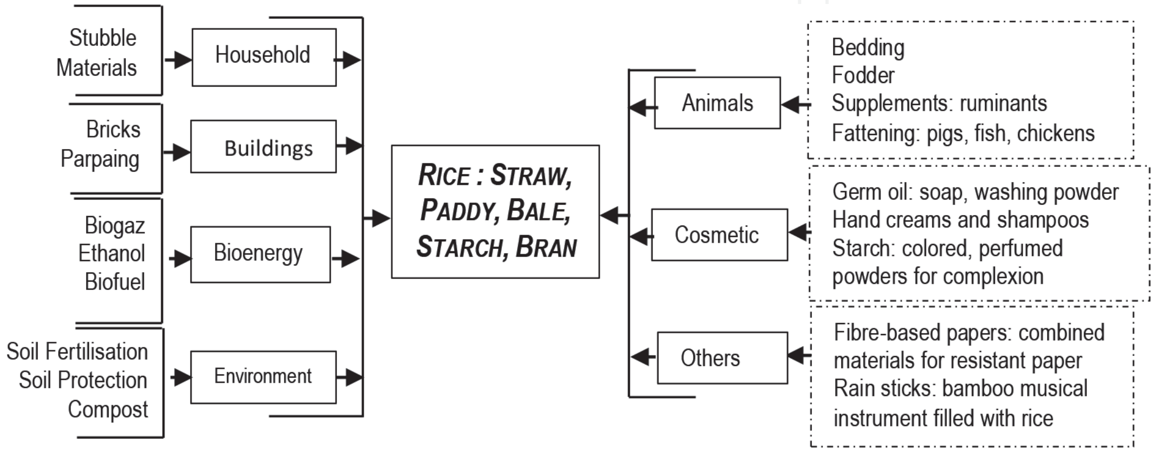


**Figure 3.**
*Applications from the rice.*

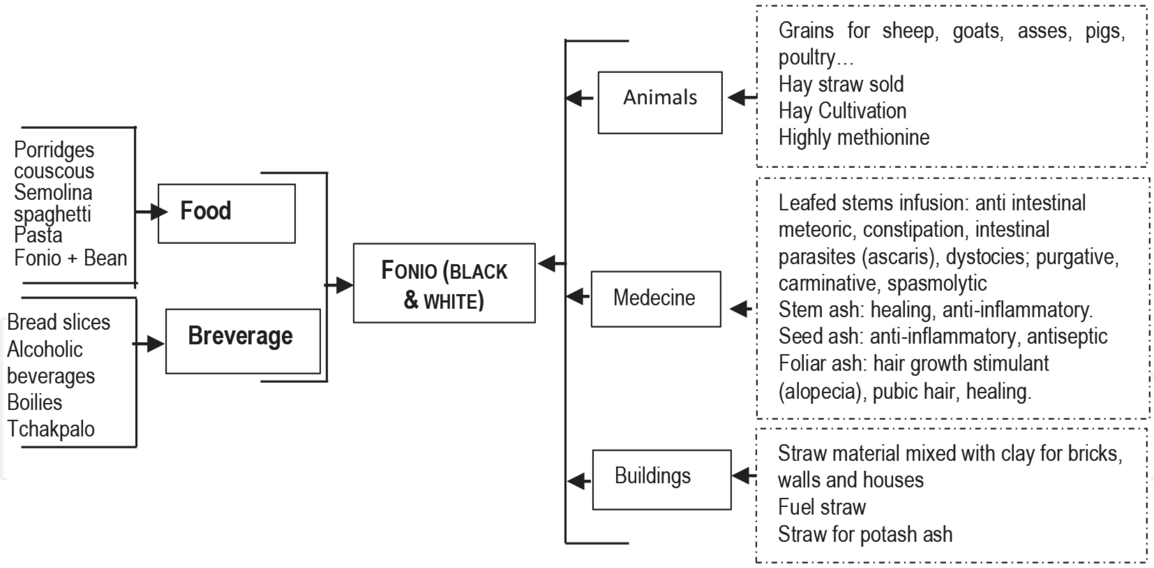


**Figure 4.**
*Applications from the Fonio.*

*Arundo donax* provides all-lignocellulosic fiberboards without synthetic binders, raw good material for fiberboard production and its pulp is rich in cellulose and moderate in lignin.

**Figures 3** and **4** highlight some applications from Rice and Fonio, respectively.

## 8. Concluding remarks

This chapter highlights some milestones in *Grasses and Grassland* research: (1) 18 types of *Grassland* identified; (2) only 250 tropical *grass* species among 9700, i.e., 2.58% studied before 1990 and 100 over the last 30 years; (3) *Grasses* have been field characterized throughout 78 parameters; (4) biodiversity results in 43 cereals and 50 tropical *Grasslands*; (5) mostly, *Grassland* of *Andropogon gayanus* and *Hyparrhenia involucrata* (74% PV, 6.28 tons DM/ha; 0.37 ha/TLU) from Guineo-Sudanese opposed *Setaria longiseta* and *Sporobolus pyramidalis* (21% PV; 2.9 tons DM/ha; 5.4 ha/TLU) from Sudanian zone; (6) cultivated *grasses* belong to *Panicum* spp., *Brachiaria* spp. and *Pennisetum* spp.; (7) cereals contain gluten from 5% in rice to 69% in wheat; (8) properties result in 7 anti-erosive, 10 ornamental, 17 medicinal, 15 cultural and 11 aromatic with 95 oil volatile compounds; (8) Twenty-seven bio-syntheses recorded with Dhurrin genetic control, mechanism of lipid metabolism pathway and vitamin C biosynthesis remaining concerns; (9) applications are bioenergetic, cosmetic, industrial and environmental with sequestering carbon and nitrogen into soil.

Otherwise, most of cereals' syntheses are found in fighting century diseases including cancers, high blood pressure, etc. that devastate human resources and thus negatively impact Nations economies.

So many virtues for more or less demanding resources like *Grasses and Grassland*! The whole world can certainly make a big profit from its. In a context of increasing difficulties in adequately feeding a growing world population threatened by major plagues, interest in these natural resources must certainly be attracted. Given the rapid precariousness of the food and health situation in some parts of the world, would it be too much to consider *Grasses and Grassland* as a hope for sustainable well-being? Whether ecological intensification is a pastoral contribution to agricultural and environmental services in a variety of systems that value permanent *Grasslands* in the forage system, what would life on earth really be without these *Grasses and Grassland*? Facing array of properties, synthesis and applications which force the hope, politicians would science-based manage for ensuring secured future for humanity, even in the increasingly alarming global warming; because *Grasses and Grassland* could be solutions to eventualities. In this debate, however, government officials, policy makers, professionals, and the general public would ensure that proactive and sustained production, processing and development, as well as commercialization of *Grasses and Grassland* are for the sustainable well-being of the respective communities; Decisions needed for sustainably managing these properties, synthesis, and applications so that serious threats can be mitigated. This includes students, teachers, and operators, who are tracking accurate and updated inventories of *Grasses and Grassland*' knowledge.

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