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REVIEWS

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Historical Review of the Stratified British Sheep Production System

Fernando Mata

CISAS –Center for Research in Agrifood Systems and Sustainability, Instituto Politécnico de Viana do Castelo, Rua da Escola Comercial e Industrial Nun' Alvares nº 34, 4900-367 Viana do Castelo, Portugal

ABSTRACT

The stratified British sheep production system is a three-tier production system that includes the hill, the upland, and the lowland subsystems. In the hills, pure-breed ewes are kept, and draft five-year ewes are brought down to the uplands where they can still have a couple of years of productive life. In the uplands, the hill ewes are mated with an upland sire. This first cross brings together hardiness, and mothering abilities to produce dams of the Prime Lamb. These are brought further down to the Lowlands where they are mated to a Terminal Sire to produce the Prime Lamb. The system takes advantage of maternal and individual heterosis and complementarity of breeds. The system marked the British sheep industry of the 20th century, however, the new challenges faced by the industry may end this unique production system. The objective of this revision is to construct a single document easily accessible to scholars explaining the Stratified British Sheep Production System.

Keywords

British sheep industry, hill, lowland, sheep stratification, upland

1. Introduction

The stratified British sheep production system (SBSPS) is an inevitable case study in livestock production systems. The system has the beauty of integrating several sub-systems into a unique chain of events between farms in different tiers. To produce prime lamb, the lowland farms, using more prolific, fast-growing, and prime carcass conformation breeds, depend on the less favourable areas in the hills, to form their flocks. This chain of events allows an economic return from the lowlands to the hills, where the production is less profitable. The system takes advantage, puts in context and considers several key aspects of animal production, reproduction, feeding, nutrition, animal behaviour, and commercialization.

Despite its importance in Britain, the system has no immediate replication in other places of the world, due to different edaphoclimatic and socio-economic conditions. Nevertheless, the system is a good case study to put in context and perspective, the different disciplines of interest in animal production science.

The system is widely used and well-known in Britain, however, the literature referring to the system is sparse and limited. Some considerations can be found in books, reports, and magazines, but few scientific journal articles refer to it specifically. This review addresses this gap, aiming to construct a text explaining the SBSPS, revealing its historical context, discussing its advantages and weaknesses, and putting in perspective its future.

2. A summary of the sheep breeding history in Britain

Sheep have been domesticated 10,000–12,000 years ago in the Fertile Crescent [1], and arrived in Britain later in the Neolithic age, approximately 4,000 years ago [2]. The Soay sheep found in the Saint Kilda archipelago of the Outer Hebrides in Scotland is reminiscent of this ancient ovine [3]. At the time Great Britain was covered by forests,

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only the mountain peaks could be grazed [4]. Later in the Bronze Age sheep spread across Britain for meat and wool and during the wet and colder Iron Age period, wool became the elected textile fibre [4]. Romans introduced the merino fine wool from Southern Europe and wool became the main reason to farm sheep and was kept as such up to the Middle Ages when meat and milk started to have increased importance [5]. In the 16th and 17th centuries, farming moved from the subsistence of feudal systems into commercial agriculture, bringing greater control on breeding as meat became as important as wool due to population growth in the expanding towns [6].

With the increasing importance of the different purposes and the migrations of people into the British Isles, different types of sheep started to shape. Pullar [6] refers to the main types of sheep populating Britain at the beginning of the 17th century:

1. The white-faced horned type spreading in Scotland and Western parts of England, from which the modern breeds Cheviot and Welsh Mountain are the most representative.
2. The black-faced horned type spreading from Berkshire and East Anglia to central England's Pennines and the Scottish mountains, reaching later also the Highlands. This group is typified by the modern breed Scottish Blackface.
3. The hornless white face arrived with the Romans and is the fine wool choice in medieval Britain. This can be further divided into [7]:
 - i. Primitive long-wool type, spreading from the Cotswolds to Lincoln in the Midlands. The primitive Romney is the origin of modern breeds such as the Border Leicester and the Teeswater.
 - ii. Old short-wool type is typical of Hereford and Sussex, being the most representative modern breeds, the down breeds such as the Southdown, Oxford Down, Hampshire Down, Suffolk, and Dorset Down.

Robert Bakewell (1725–1795), has been identified as the first farmer to establish pedigree livestock breeding in Britain, having achieved success mainly with sheep [8]. Bakewell worked around longwool breeds and achieved great success with Lincoln, Romney, and Border Leicester. Blackwell and some other local farmers formed the Dishley Sheep Society, and as a consequence, most of the modern British longwool breeds have Dishley blood in their ancestry [9]. Fussell & Goodman [10] cite two other authors estimating the number of breeds at the beginning of the 19th century. Culley [11] estimates 14 varieties of British sheep, while Parkinson [12] enumerates 37 British breeds of sheep.

At the time wool was a very important product in Britain benefiting from the industrial revolution that was starting to evolve in the last quarter of the 18th century [13], but as the population migrated to towns to work in factories, meat became the commodity of choice in sheep farming [14]. The Victorian age was the time for the breed pedigree development of livestock and domestic animals, and during the late 18th century livestock shows become popular [15]. During the late Victorian age, towards the end of the 19th century, most of the Breed Societies were established. Modern British sheep breeds were all developed towards meat production [5], and the Southern Hemisphere (Australasia, South Africa, and South America) become the production centre for wool.

This was also the time of the industrial revolution and the introduction of the quadrennial Norfolk rotation that included sown pastures with legumes such as clover and fodder crops such as turnips between winter and spring cereals. This was a huge improvement allowing the integration of crops with animal production. Crops benefitted from the increased availability of manure while grazing animals benefitted from the availability of improved pastures and forages. In consequence, crop and animal productivity doubled [16]. The increased demand for meat was the opportunity for the development of the first breed with carcass conformation concerns. Ellman and later Webb developed the Southdown to a deep-fleshed and early maturing lowland breed [9]. Similar to the modern longwool breeds and Dishley, all of the modern lowland breeds also have their ancestry with Southdown blood [9].

In the first half of the 20th century, there was a decline in the sheep population of Britain, especially in the lowlands in which crop production took over grazeland [17]. In the second decade of the 20th century, pure-breed

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sheep with pedigree were still considered the best for meat production, and at the time 34 sheep breeds were considered to exist in Britain [18]. During the 20th century livestock breeding science evolved and the concepts of hybrid vigour were applied to animal breeding [19]. The stratification of the British sheep industry has evolved during this stage [20]. Nevertheless, [21] tracks down to 1870 the crosses between Border Leicester rams and Scottish Blackface and Cheviot ewes to produce Greyface and Halfbreed lambs. The author, however, refers that only after World War I, these halfbreeds started to be brought down to lowlands in Scotland to cross with down breeds for the production of early maturing, good meat carcass lambs.

Accordingly, the three-tier system arose out of the general upheaval during the Great War of 1914–1918 [22]. As the lowland was increasingly being used for cash crop production, sheep farmers started seeking hill and upland stock to replace culled ewes in their flocks. The stratified production system uses specific crossbreeding to take advantage of hybrid vigour and complementarity to bring together, the best of the different breeds: hardiness, prolificacy, growths, and carcass conformation [23].

Nowadays, Britain has 75 breeds with Breed Societies registered in the National Sheep Association [24]. The list is not exhaustive, and some other breeds can also be found in Britain (mainly Rare Breeds). The list includes exotic breeds imported with a stud book established in the UK, mules, primitive breeds, the traditional three-tier breeds, and a group with others including a milk breed, composites, and rare breeds. The traditional three-tier breeds can be categorised into three groups (the hill breeds, the upland breeds, and the lowland or down breeds). The three-tier groups and the mules will be given particular attention once they are in the scope of this review. The different breeds with relevance for this revision are introduced in the following sections.

3. The three tiers of production

The British sheep industry has unique features at the global level. It makes use of a three-tier stratified structure where different tasks are developed in different farms interacting for the benefit of all those involved. The three tiers are the hills, the uplands, and the lowlands. These different tiers are populated by different types of breeds, bred to adapt to particular local circumstances. While some farms in the different tiers keep sheep in pure breed, others proceed in a collaborative breeding strategy using crossed breeds to take advantage of heterosis and produce Prime Lamb. The system evolves from the hills to the uplands and from the uplands to the lowlands, where productivity is greater. However, the farmers in the hills and upland benefit from the greater productivity in the lowlands once they also have a role to play in the production of this Prime Lamb.

3.1 The hills

The system is prevalent in Scotland, Wales, and the Apennines and Cheviot in England. These farms are normally located from 300 to 1,000 m above sea level [25]. Sheep in the hills are managed mainly in extensive systems, in larger flocks, and the environmental conditions are very hard not only from the direct influence of the climate but also from indirect influence on plant growth. Forage availability is very seasonal, and their nutritive value is not as good as that of pastures sown with grasses and legumes at lower altitudes [26]. Occasionally in some farms, young female replacements winter away in lowland more protected areas [27]. The extensive system of production also poses challenges to sheep's health and welfare. The farmer is not present at all times and sheep are not supervised as those in more intensive systems [28]. The flocks are large and may have between 800 and 1,000 ewes on average [29]. The shepherd/ewes ratio is very low [28], and as a result, injury, disease, or parasitism may not have immediate assistance [29]. Poorer nutrition has an obvious impact on prolificacy and in the hills, no more than 0.8 lambs per ewe are expected on average, or 0.6 to 1.2 in better farms [22]. Concentrate feeding is almost

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inexistent during most of the year [30], however, some supplementation has been more frequent in recent times, especially for flushing [29]. The stocking rates are low with no more than 0.5–2 ewes/ha [28].

The breeds commonly found in the hills are those presented in Table 1. From these, the more representative group includes the Welsh Mountain in Wales, the Scottish Blackface in Scotland, the Swaledale in the North of England [31], and the Cheviot [32] or Herdwick [30] in the Scotland and England borders regions.

These mountain (hill) breeds have particular characteristics that allow them to adapt to the particularly hard conditions found on these farms. Twin parturitions on hill breeds are less common than in the upland and lowland breeds. Dwyer and Lawrence [33] refer that while a Blackface ewe in typical hill environments produces single lambs, about two-thirds of the Suffolks in lowlands give birth to twins. Nevertheless, hill sheep carry heavier lambs (in proportion to their body weight) [34]. Hill ewes demonstrate a parturition behaviour that is closer to their wild counterparts when compared to that observed in lowland breeds. Hill ewes seek isolation, the delivery is easier and the labour time shorter. The process of domestication and intensification with increased human contact may have contributed to a change of behaviour as lowland sheep more frequently ignore their newborn lambs or at least do not assist them as promptly as hill breeds do [35]. The maternal instinct is, therefore, stronger in hill breeds, which allows a quicker ewe-lamb bond establishment and access to colostrum [34], accounting for a lower risk of exposure to conditions leading to hypothermia, starvation, and septicaemia [25]. The colostrum itself is also richer in hill breeds, containing higher lipidic content, contributing to improved thermoregulation and nutrition [34].

The lambing dates in hills are middle of Spring (late April and May), to allow grass availability for the nourishment of the lactating ewes [36]. In consequence, ewes are put to the ram for tupping in late November and during December. The lambing season is very concentrated to allow lambs to be weaned before the end of the Summer. Most males are sold at the end of the Summer as stores to farmers at lower altitudes that finish them before slaughter [37]. However, from 50% of carcasses failing the targeted grade in British abattoirs, the majority come from hill breeds, impacting the economic return of the hill sheep farm [38]. Male lambs are sold mainly as “stores” in the Autumn with about 25 kg [22].

A unique feature of the hill production systems is that the income is also complemented by ewes that are sold after 4 or 5 lambing seasons, still with reproductive potential for a couple of lambing cycles [39]. This is not culling as ewes are still productive if brought down to less harsh environments, such as the uplands. The process is known as “drafting” and the ewes will have a productive life of 2–3 more seasons [22]. Drafting ewes also allows a quicker turnover of the hill flock that is kept stronger, with younger ewes [22]. Nevertheless, not all ewes after 4 or 5 lambing seasons retain productive potential, and some are culled and sold for mutton [29].

The hill farms keep all the female lambs as replacers, and hogget females are commonly wintered away, in lowland farms, with silage, root crops, and hay or at home in sawn fields, as the first winter may be difficult to overcome [9, 22, 38]. This is known as “agistment” or “tack” [22]. Another interesting feature of some hill farms in Britain is that some flocks are bound to the land and if the land is sold the flock goes with it. This block of land is known as “heft” and the system is known as “hefting”. In this peculiar system, the flock is closed to outside entrances with the expectation that a better adaptation to the specificities of the local and the production system may evolve naturally [40]. “Hefting” is a practice that can be traced back to the 17th century [40]. In the hill, some farms, mainly in the Scottish Highlands, are managed in a “crofting” system. “Crofts” are relatively small holdings of enclosed grassland (the “inbye”). The farmers use then shared rights in common grazing land “the commons” in the hills [41].

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Table 1: Most common British breeds with Societies registered in the National Sheep Association. Some other rare breeds could also be added. Source [24]

	Breed	Origin	Society Established
Mountain Breeds	Badger Face Welsh Mountain	1 st century	1976
	Balwen Welsh Mountain	19 th century	1985
	Beulah Speckled Face	19 th century	1958
	Black Welsh Mountain	18 th century	1920
	Scottish Blackface	12 th century	1901
	Cheviot	14 th century	1890
	Clun Forest	19 th century	1925
	Dalesbred	----	1925
	Derbyshire Gritstone	1770–1775	1906
	Epynt Hardy Speckled Face	----	1976
	Hill Radnor	1911	1949
	Kerry Hill	1809	1899
	Llandoverly Whiteface	----	1998
	Nelson South Wales Mountain	----	1948
	North Country Cheviot	18 th century	1945
	Rough Fell	Middle Ages	1926
	Swaledale	12 th century	1920
	Talybont Welsh	----	----
	Valais Blacknose	15 th century	1962
	Welsh Hill Speckled Face	20 th century	1969
Welsh Mountain	Middle ages	1905	
Hill Breeds	Bluefaced Leicester	19 th century	1963
	Border Leicester	18 th century	1898
	Exmoor Horn	19 th century	1906
	Herdwick	12 th century	1916
	Romney	13 th century	1895
	Teeswater	19 th century	1949
	Wensleydale	1839	1890
	Whitefaced Woodland	17 th century	1986
	Bluefaced Leicester	19 th century	1963
Lowland Breeds	Dorset Down	19 th century	1906
	Hampshire Down	19 th century	1889
	Oxford Down	1830s	1889
	Ryeland	12 th century	1903
	Southdown	17 th century	1893
	Suffolk	1810	1887
	Wiltshire Horn	1 st century	1923

Note: ---- information not available

3.2 The uplands

Upland sheep farms are prevalent in Southern Scotland, Western Wales and in the lower altitudes of the Apennines, at altitudes between 150 and 300 meters [25]. Sheep are managed in a semi-intensive system, with some sown pastures. Forages may also be stored for wintering. Most of the grazing land is poor but divided into paddocks to allow sheep rotation [9]. Fertilizers may also be used in some fields [22].

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The conditions for grazing are now much better than those observed in the hills. The main grazing season extends from May to the middle of October and the stocking rates can now typically reach 4 to 6 ewes per hectare [42]. Prolificacy increases in comparison to hill systems from 0.8 to 1.55 lambs per ewe [22]. Twin lambings are therefore observed with some frequency. The flock sizes are smaller than those in the hills and have an average size of approximately 500 ewes [43]. Sheep are also more regularly seen by the shepherds, especially at tugging and lambing. Productivity may improve up to 40%, when compared to hills, due mainly to an increased prolificacy and lower barrenness incidences [22].

The breeding season is now larger, reflecting the larger period of grass availability. Tugging takes place from mid-September to the end of December and lambing occurs from February to May [29]. The system may use pure breeds only or may use crossbreeding. Crossbreeding uses the draft ewes from the hills that were purchased mainly in market auctions and an upland breed sire. Most crossbred lambs are sold as “stores” in September, some are kept, castrated and finished and ewe crossed lambs are also finished to be sold as ewe “hoggets” to lowland farms [22].

The crossbred ewes obtained in the uplands are valuable reproducers that are sold to lowland farmers to be the dams of prime lamb. These crossbreeds are recognised within the British sheep industry by specific names, and some even have their own breed society registered with the National Sheep Association. The two most common upland breeds used in the production of these crosses are the Border Leicester (and the crosses are named “Halfbreeds”) and the Bluefaced Leicester (the crosses are named “Mules”). Table 1 presents the most common upland sheep breeds in Britain, and Table 2 presents the most common crosses in Britain. Bluefaced Leicester dominates as the prolificacy is normally higher in this breed. A litter size increase of 6% when compared to Swaledale and Scottish Blackface was reported by Cameron *et al.* [44].

The cross aims to exploit the complementarities of breeds and the heterosis effect [39]. Hill breeds can bring hardiness traits, while upland breeds bring litter size and milk production traits. The maternal heterosis is searched for growth and carcass traits [39].

The upland sheep farms sell all the males for slaughtering after finishing or sell them as store lambs to lowland farms for fattening [22]. The females are sold as “hogget” to lowland farmers as flock replacers, to be the dams of Prime Lamb.

While some farms buy the “draft” ewes from the hills and upland sires to produce these crossbreeds, other farms maintain purebred flocks. All these systems produce slaughter lambs with carcasses weighing 18 to 20 kg [29] and “mutton”.

Table 2: Most common crossbreeds produced in the uplands. Some other rare breeds could also be added. All crosses had their origin in the 20th century. Source [24].

Crossbreed	Sire (upland)	Dam (hill)	Society Established
Masham*	Teeswater	Dalesbred	1986
North of England Mule*	Bluefaced Leicester	Hexham Blackface or Swaledale	1980
Scotch Mule*	Bluefaced Leicester	Scottish Blackface	1986
Welsh Mule*	Bluefaced Leicester	Welsh Mountain, Beulah or WHSF	1978
English Halfbreed	Border Leicester	Swaledale	----
Greyface	Border Leicester	Scottish Blackface	----
Scottish Halfbreed	Border Leicester	Cheviot	----
Welsh Halfbreed*	Border Leicester	Welsh Mountain	1955

Notes: *with societies registered in the National Sheep Association; WHSF – Welsh Hill Speckled Face; ---- information not available.

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3.3 The lowlands

Lowland sheep farms are traditionally located in valleys across Britain and the East of England in land intensively used in rotations including cash crops. The average flock size decreases (in comparison to hill and upland farms) to approximately 360 ewes per holding [45]. Lowlands are typically located below 150 meters above sea level [25].

Lowland grazing fields are enclosed paddocks with sown premium species of grass such as perennial ryegrass (*Lolium perenne*) and legumes such as white clover (*Trifolium repens*) allowing stocking rates to reach 12.5 ewes per hectare [46]. Sheep are farmed intensively, and forage supplementation is available when necessary and includes silage, hay, fodder crops, crop farming by-products, crop industry by-products, and concentrate. Lambs may be finished in a variety of feeds that include all these feeds [22]. These are sold through Autumn and Winter and include store lambs purchased from upland and hill farms [9, 22].

The breeding season is extended from early March and synchronization for out-of-season lambing can also be practiced [47]. In consequence, winter lambing may occur indoors, and extra care is provided to both ewes and newborn lambs [48].

Lowland farmers buy the Mules or Halfbreeds produced in the uplands and cross them with a terminal sire to produce prime lamb. The crossbred dams with maternal heterosis reach a prolificacy of 1.7 lambs per ewe. The lambs coming out of these crosses are the Prime Lamb of the British sheep industry. They grow faster and meet the targets for a carcass conformation of excellence.

Several lowland breeds may be used as Terminal Sires (Table 1), including some exotic breeds such as Texel or Charollais. These lambs have very high performances reaching about 30 kg at weaning (90 days) and 45 kg at the sale (200 days), with net carcass weights of 20 kg (lambs from North of England Mules sired with Texel or Charollais in a forage-based system) [49].

4. The integration into a stratified production system

The three systems (hill, upland, and lowland) can be viewed as subsystems of a larger production system, the SBSPS. Each of the subsystems has a different role in the major system, and the interdependency becomes evident (Fig.1). In Figure 2 the different SBSPS tiers' locations within the UK can be observed together with some illustrative pictures of breeds and landscapes.

The hill subsystem produces “draft ewes” from hill breeds to be used by the upland in a first cross with a longwool breed to produce “Mules” and “Halfbreeds”. The upland subsystem then sells the crossbred ewes to the third subsystem involved, the lowland. Finally, the lowland subsystem uses the crossbred ewes and introduces the second cross to a terminal sire to produce the Prime Lamb.

While the structure outlined in Figure 1 gives an overall view of the SBSPS, we have to consider that in reality, a mix of options is in fact practiced, and some exotic breeds have increased their share as terminal sires. Nevertheless, in this review, we will concentrate our attention on British breeds only.

The contribution of each of the three subsystems for the whole SBSPS can be consulted in Table 3. A significant proportion of the lambs produced are not Prime Lamb, these in fact are a minority, and Prime Lamb represents only 8.4% of the total crop of lambs generated by the British sheep industry. Interestingly, Pollott and Stone [59] refer to the matching between the type of Less Favoured Area (LFA) used in the 1980s and the different tiers of production. Hill production systems are observed where the level of the LFA scheme has higher support and upland production systems are observed where the LFA level of support is lower. The lowland systems are observed in non-LFA areas.

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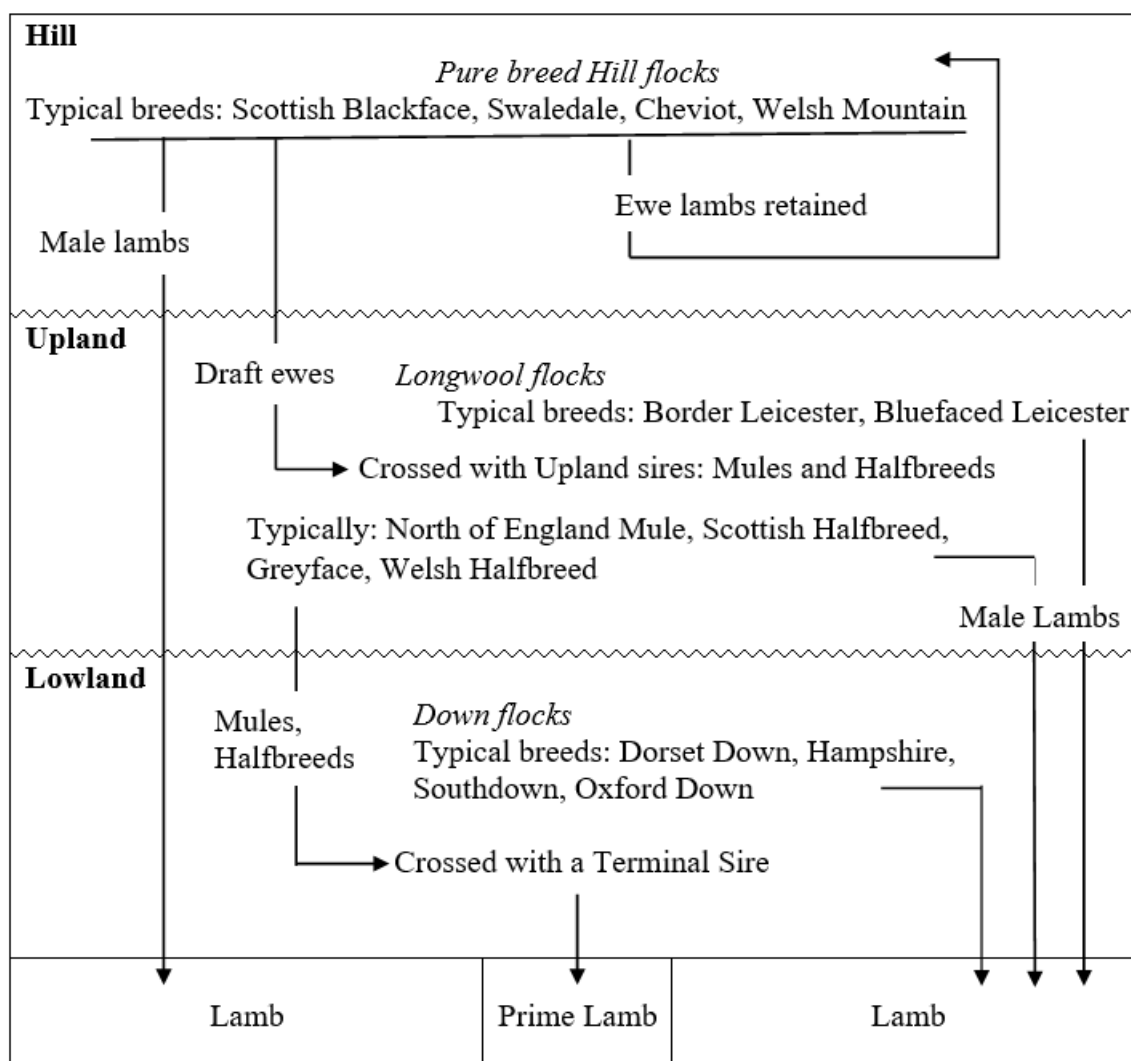


Figure 1: Schematic representation of the three-tier stratified British sheep production system.

Different breeds and crossbred types contribute differently to the whole system. Also, these different breeds and crosses have different weights in the British sheep industry (see Table 3). These proportions, however, have been changing throughout the years, as will be discussed later. As can be observed, the crosses between the hill and upland breeds were dominant with more than 32% of the slaughtered lamb produced here. The purebred ewes from the hills have also a major contribution with 24% of the lambs slaughtered originating here. According to Pollott and Stone [59] the major contribution of these two groups reflects the mothering ability of hill ewes and the prolificacy of the hill crosses with uplands.

The terminal sire breeds dominate the parental progeny of the different lambs in Britain (71% see Table 3). Another important group is the hill breeds, as this type of breeds dominates in Britain and is generally kept as pure breed. About 16% of the hill breeds were responsible for the British lamb crop in 2003.

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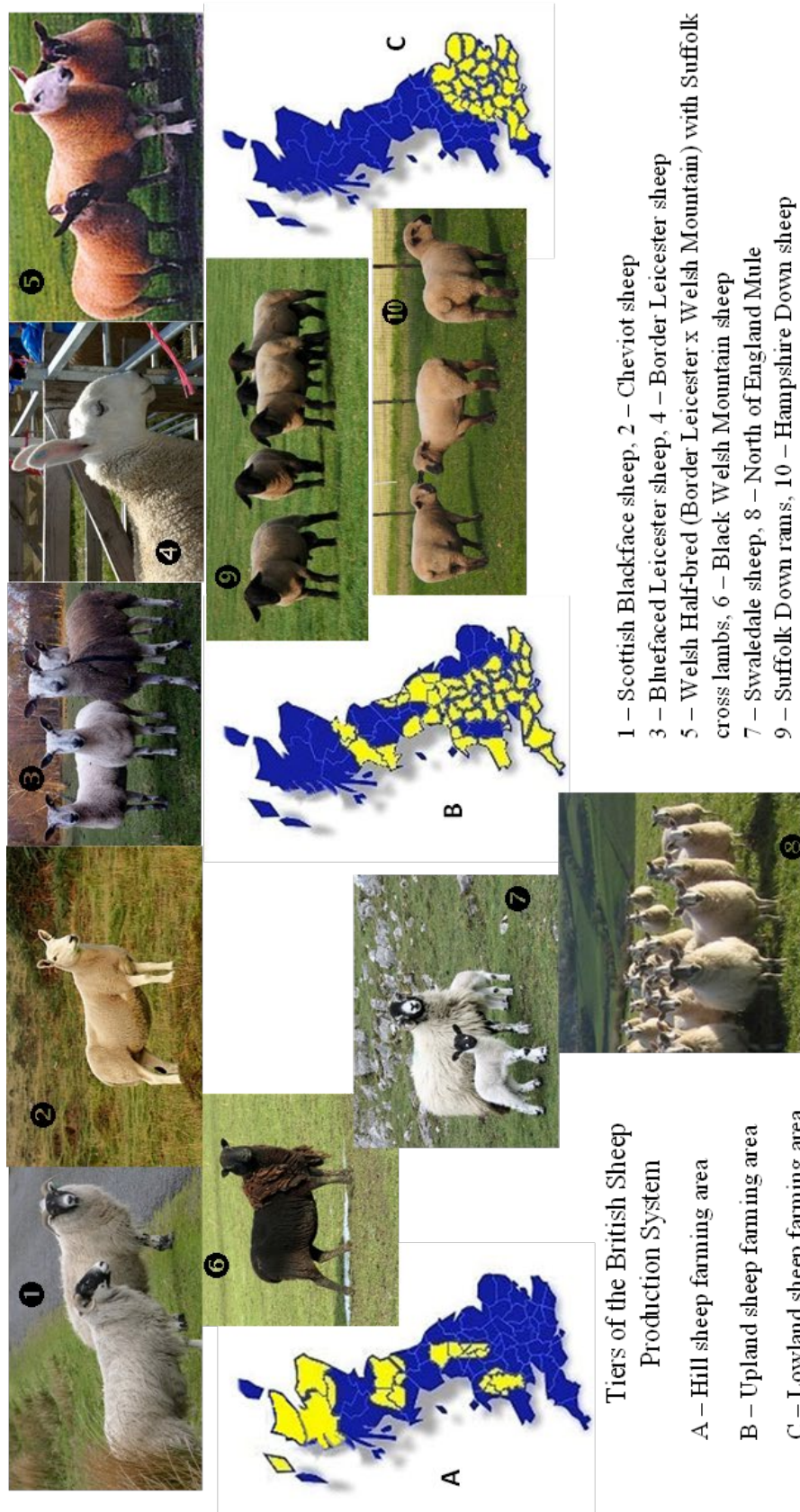


Figure 2: Outline of locations within the UK where the different tiers of the Stratified British Sheep Production System can be found. The maps are also illustrated with pictures of some specific breeds and landscapes. Sources: 1 [50]; 2 [51]; 3 [52]; 4 [53]; 5 [54]; 6 [55]; 7 [55]; 8 [56]; 9 [57]; 10 [58].

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Table 3: The proportion of the contribution of the different breed types to the overall output from the British sheep industry in 2003 (percentages). Adapted from Pollott and Stone [59].

Breed type	Dams of lambs	Sires of lambs	Lambs slaughtered	Lamb meat
Hill	48	16	31	27
Mules/Halfbreeds	22	6	14	15
Terminal Sire	18	71	44	47
Other	12	7	12	12
Percentage of the lamb crop				
	Hill			23.9
	Mules/Halfbreed			32.7
	Terminal Sire x Mules/Halfbreeds (Prime Lamb)			8.4
	Terminal Sires			5.4
	Other			29.6

Between the upland breeds used as Sires in the production of crosses with hill breeds, the Bluefaced Leicester dominates, and in fact, nowadays Border Leicester is already considered a rare breed [60], due to the differences observed in performance, namely in prolificacy as evidenced in Table 4.

Table 4: Performance of Crosses in lowland farms in 1989. Source [61].

Breed Cross	Prolificacy (lambs/ewe)
North of England Mule	1.71
Scottish Mule	1.57
Welsh Mule	1.58
Scottish Halfbreed	1.51
Welsh Halfbreed	1.45

The Mules/ Halfbreeds obtained in the upland sub-system benefit from the hardiness of the mountain breeds, and the prolificacy of the upland breeds. The cross takes advantage of maternal heterosis in the production of Prime Lamb. The Scottish Blackface is a heavy hill breed, while the Welsh Mountain is very light. Welsh Mountain is a harder breed when compared to Scottish Blackface. Welsh Mountain and Swaledale grow faster during the suckling period, as both breeds produce milk in quantity and quality.

In terms of down breeds, the Oxford Down is the heaviest, followed by Suffolk, being Southdown the lightest of these breeds. The lambs’ weight at birth reflects the adult weight of the dams. These performance aspects can be consulted in Table 5.

Overall, the lowland subsystem has the higher contribution to the British sheep industry with 48% of the lambs produced originating here. As the largest carcasses are produced here, the lowland tier is responsible for 71% of the lamb meat produced overall. These figures are also the result of store lambs transferred from the other tiers (mainly hills) to lowland farms, where they are finished. The hill subsystem follows in terms of breeding ewe figures, however, the difference in terms of total meat produced the difference to lowland farms is much higher reflecting the huge quantities of store lambs transferred from hills to lowlands.

In terms of carcass conformation, to obtain the same fat classification, the different breeds need to be slaughtered at different points in time and with different weights. Dorset Down and Southdown are early maturing breeds needing a shorter period of fattening, while Oxford Down and Suffolk mature later with larger carcass weights. Border Leicester and Cheviot, upland and hill breeds respectively, lacking specialization for meat production, mature very late in contrast with the down breeds [62]. These breeds have relatively lower weights than specialized breeds

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when grown to the same age. The contrast between down breeds and the others in terms of carcass conformation is also evident.

Table 5: Performance of different British sheep breeds originated from one of the three tiers or sub-systems, plus Mules and Halfbreeds. Source: The Sheep Improvement Services from the Meat and Livestock Commission. Reported by Croston and Pollot [22].

Breed Group	Breed	Mating Weight (kg)	Prolificacy (lambs/ewe)	Birth weight (kg)	8-week weight (kg)
Hill	Scottish Blackface	54	1.46	3.8	17.3
	Swaledale	48	1.49	3.4	18.2
	Welsh Mountain	35	1.18	2.9	13.5
Upland	Bluefaced Leicester	86	2.24	5.1	22.7
	Border Leicester	83	1.86	5.8	22.8
	Teeswater	86	2.15	5.9	21.4
Lowland	Dorset Down	74	1.41	4.8	18.6
	Hampshire Down	72	1.41	4.6	20.1
	Oxford Down	89	1.39	5.6	22.3
	Southdown	55	1.49	3.7	16.0
	Suffolk	83	1.71	5.2	21.6

Lambs in Britain are targeted for slaughtering under a constant percentage of subcutaneous fat of 11% (corresponding to the midpoint of fat class 3) and there is a linear relationship between time for slaughter and carcass weight [62].

The choice of Terminal Sire influences the production of Prime Lamb. For example, the Oxford Down is the breed of choice in a flock of Scottish Mules, showing to grow faster than Dorset Down and Suffolk [63].

The Terminal Sire isn't the only ancestor to be chosen, and depending on the production system some breeds may perform better than others. A study by Wolf *et al.* [63] shows that Prime Lamb obtained from Dorset Down sire crosses with Scottish Halfbreed dams mature later than when using Hampshire sires and finishing the lambs off-grass. However, if the dam is the North of England Mule, the off-grass lambs mature later. Similarly, while using Oxford Down or Suffolk as Terminal Sires, the same type of variations is observed. The Breed is not the only factor to consider in terms of variability of performance, as the production system has its influence as well. While comparing the performance of Southdown sires, we can observe that Prime lamb is maturing early if a Scottish Halfbreed is used in an off-grass finishing system, while in a system using also forage crops and roots, the early maturation is observed for the North of England Mule.

It is therefore acknowledged that depending on the production system, dam crosses available and the marketing targets, different breeds may be used as sire and/or dam, in the lowland tier.

5. Discussion

5.1 Advantages

The major advantage of the SBSPS is the heterosis and the complementarity effects of the different breeds. Each breed in the different subsystems has a specific genetic pool resulting in distinguishing phenotypes conveying specific characteristics. Pure breeds have higher levels of homozygosity and when these pure breeds are crossed, the new combinations of genes increase heterozygosity which is the cornerstone of heterosis or hybrid vigour.

Complementarity is defined as the improved production efficiency resulting from bringing together in a cross of the best of two breeds [64]. Each breed has positive and negative performance aspects.

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The SBSPS takes advantage of two types of heterosis, maternal and individual heterosis. The crosses between the hill and upland breeds to produce the Mules and Halfbreeds, takes advantage of maternal heterosis. The prolificacy of Mules and Halfbreeds is improved by heterosis. The ewes produced out of this cross have improved mothering abilities, prolificacy, and milk production. This cross is also able to complement the mothering instinct and milking ability of the mountain sheep, with the prolificacy of the upland breeds.

In the second cross of Mules/Halfbreeds with a Terminal Sire, the aim is to produce Prime Lambs with individual heterosis. These lambs have improved growth performances and excellent carcass conformations. The Prime Lambs also take advantage of the improved mothering traits of the Mules and Halfbreeds complemented by the meat production traits of the Terminal Sires. Prime Lambs are weaned heavier and are finished faster achieving also better carcass gradings.

The combined effects of maternal heterosis, individual heterosis and complementarity can increase productivity by 40 to 50% in relation to the average performance of the purebreds involved [64].

Another great advantage of the SBSPS is the redistributive effect on the income of farms. Lowland farms produce Prime Lamb sold at more competitive prices, however, part of this income is redistributed into the upland and hill farms, as these are responsible for the production of the Prime Lamb dams. The lambs produced on this grass have higher contents of omega-3 fatty acids. Sheep are capable of turning the low-value vegetation in the hills into highly valued protein.

Finally, we also have to consider social and environmental aspects [65]: hill and upland sheep play an important role in maintaining the mountain landscape and biodiversity, and also preventing the accumulation of shrub vegetation that otherwise would accumulate as potential fuel for wildfires; hill and upland farming also provide a valuable source of quality water, and contribute to carbon sequestration; hill and upland communities, of which farmers play a pivotal role, provide a wealth of health and social benefits for residents and visiting tourists.

“Hill farming is vital to the landscape and wildlife of Britain’s uplands. Without continued livestock grazing, and in particular, by sheep, many of the English national parks and areas of outstanding natural beauty would become unrecognizable and inaccessible to the general public” [30].

5.2 Disadvantages

The major disadvantage of the SBSPS is the diversity of sorts of slaughtered lamb produced leading to a variety of conformations lacking uniformity and hindering industrial processing [9].

Another identified weakness is the possibility of short-term supply problems of ewes from hills and uplands, which can distort Prime Lamb dam prices. It is difficult to find a balance between the Prime Lamb dam supply and demand [22].

Finally, another problem is the regular transfer of sheep between farms as it brings an increased risk of disease spread and transmission [66]. Croston and Pollot [22] give an example of infectious abortion, capable of imposing serious disruption and loss in lowland flocks.

All these aspects impact the income of farmers. With Brexit and the new commercial alliances with countries such as New Zealand and Australia, Britain faces increasing imports of frozen lamb with premium homogeneous conformations, very attractive to the meat industry in Britain [67].

6. Future directions

The UK entered the EU in 1973 and at the time with the benefits of the Common Agricultural Policy (CAP), the income from sheep farming increased substantially. As result, an increase of 10% in the 1970s and 25% in the

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1980s was observed in the number of sheep in Britain [9]. During the 1990s with the reforms in the CAP the number of ewes eligible for subsidies was limited and a decline in figures was observed again [22] (Table 6).

Table 6: Breeding sheep numbers from 1971 to 2020 (Source [68]), number of crossed ewes (upland x hill) (Source [69]), and number of ewes in the Stratified British Sheep Production Sheep (SBSPS) (Sources §[31] †[68]).

	1971	1987	1996	2003	2012	2020
Ewes mated	11,962	17,375	16,860	14,377	----	----
Ewe hoggets mated	----	1,763	1,194	812	----	----
Total ewes mated	----	19,138	18,054	15,189	13,064	12,957
Ewe lambs not mated	2,435	2,103	2,528	2,476	----	----
Rams used	325	487	471	412	365	364
North of England Mule	311	3,233	3,809	1,915	2,094	2,154
Welsh Mule	----	370	631	738	330	390
Scottish Mule	----	502	263	610	231	282
Greyface	214	332	156	212	90	47
Welsh Halfbreed	304	410	250	130	28	13
Scottish Halfbreed	590	346	162	100	19	19
Masham	406	249	162	56	32	18
Suffolk x Mule/HF	550	603	495	590	662	579
Texel x Mule/HB	0	32	220	307	862	1,273
Ewes in the SBSPS (%)	§86	----	----	§71	§55	†46.8

Note: ---- information not available.

While the number of sheep in the UK has been decreasing, the SBSPS is also in decline. The percentage of ewes in the stratified UK sheep production system has been decreasing. Several other production systems have been evolving and the introduction of exotic breeds is rising. Table 6 summarises the changes.

With the decline of the SBSPS an increase in the role of Texel as a Terminal Sire is observed. The role of Border Leicester is also in decline and while the figures for Mules are stable, the decline in the figures for Halfbreeds and the Greyface is evident. Other upland breeds such as the Teeswater, responsible for the production of Masham Mules, are also in decline.

With the decline of the SBSPS, the hill farmers are those at higher economic risk, and the dependency on subsidies and the diversification of activities is becoming evident. In 2018 it was calculated that only 40% of the income in hill farms was actually prevenient from farming. Another 30% comes from the diversification of activities and 30% was coming from subsidies [70].

The decline of the SBSPS was caused by a reduction in purebred ewe numbers maintenance of figures for upland crossbreedings and lowland, and the overall decline in the numbers of sheep in the UK [31, 36, 54, 70, 71]. Pollott [31] refers to the increasing number of *had hoc* crosses and the wide number of exotic breeds being introduced in Britain.

Some authors refer that the SBSPS may be in danger of subsisting mainly because the contribution of the hill's sheep genetics is not as essential for lowland farmers as it was in the past [72]. Fraser *et al.* [73] refer that other commercial breeds can replace the traditional with the same type of benefits for the production off-grass. Other authors add that traditional breeds cannot fully express potential on pastures managed extensively [74]. These economic pressures have decisively contributed to the decrease in traditional breeds [75]. New breeds have gained space and popularity between farmers, such as the composite breeds Easycare, Highlander, Lleyrn, and Aberdale.

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The quickly changing world is continuously posing new challenges to the British sheep industry. In an exercise trying to predict the future of the sheep industry, Scotland's Centre of Expertise on Animal Disease Outbreaks established four potential scenarios [76]:

1 –Sheepishly Smart– Driven by the need to minimize GHG production. The sheep industry concentrates on lowlands using high-performing sheep in semi-intensive systems to avoid fertilizers and fuel use. An opportunity is identified as beef may be taxed to avoid methane emissions. The spread of the Thoka gene may be responsible for an increased prolificacy of up to four lambs per ewe.

2 –Opportunity knocks for some– The traditional SBSPS disappears. Lamb prices are volatile, subsidies have been removed, and only professional farmers with expanded flocks will be able to compete.

3 –Three bags full– Support to the sheep industry has been enhanced with technological developments. Technology boosts the industry, keeping it competitive. From robotics to genetics and veterinary treatments, sheep farmers benefit from advances in the digital age. Drones replace shepherd dogs patrolling the hills where large flocks are kept.

4 – Silence of the lambs– Lamb demand is low and local. The production costs for lamb remain relatively high compared to other countries. Cheap protein production from chicken is the priority for the increasing global human population, there is no significant export demand for lamb.

7. Conclusion

The SBSPS marked sheep farming in the UK during the 20th century. As we entered the 21st century, the system has been replaced with the introduction of exotic and composite breeds. Nevertheless, the British sheep heritage will continue to mark the history of sheep farming in the UK. Farmers especially in the hills and uplands will have to reinvent themselves as the lowlands become less dependent on dams brought down from those areas, to produce lamb at more competitive prices. Since Brexit, Britain lost access to the European markets that used to buy lamb produced in Britain. On the other hand, the UK now has increased competitions from countries such as New Zealand capable of producing at high standards of carcass conformation at low prices.

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