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FEED USE ESTIMATION: DATA, METHODOLOGIES AND GAPS - THE CASE OF THAILAND

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1. Introduction

In Thailand, livestock plays a very important role as an integral part of farming and rural life, providing food, family income and employment. Within the context of world population growth and economic development, consumption of animal products has been increasing, accompanied by increasing regulatory pressures related to food security/safety concerns, and concerns about environmentally sustainability. All of these factors have affected the livestock industry.

Growing food and feed demand (influenced by rice and cassava availabilities as well as pork and chicken exports) as well as investments in the bio-energy sector have influenced prices of feed grains and induced land use changes (e.g. from corn, cassava, and sugarcane to rubber tree, palm oil, etc). It is clear that there is a growing need for more precise assessments of current and future food-feed supplies as well as more accurate estimates of livestock product consumption, all of which contribute to better and more effective national food security planning and policy formulation. Certainly the availability of national feed resources needs to be assessed and monitored to facilitate the development and implementation of appropriate policies for sustainable development.

This paper analyses the changing patterns of feed grain production and utilization in Thailand. The objective of the study focuses on the methodologies used to estimate feed utilization, reviewing data collection processes as well as identifying knowledge gaps.

2. Methodologies of food - feed estimation system

2.1. Data collection and sources of information

In Thailand, anticipating the need for better feed assessments, animal feed databases have been developed to collect and analyze developments related to national feed inventories and feed balance sheets (Annex 4) are compiled, deriving information from the official statistical systems.

National statistical institutions as well as associations that have specific responsibilities for the collection, compilation and reporting of agricultural statistical data used in this study include: the Department of Livestock Development, the Office of Agricultural Economics, the Thai Feed Mill Association, and research articles and other documents.

According to the National Statistical Office, the agricultural and rural statistics system in Thailand is decentralized with the main agencies responsible for agricultural statistics being the National Statistical Office (NSO) and the Office of Agricultural Economics (OAE). The NSO is a government agency with a departmental status under the Ministry of Information and Communication Technology. It plays the leading role in producing basic statistics at national and regional level and serves as the coordinating body for all statistical activities of government agencies.

The Office of Agricultural Economics, on the other hand, is a Governmental organization under the Ministry of Agriculture and Cooperatives which has an important role in guiding the country's agricultural development. Its mandate is the collection of statistics on agricultural economics and agriculture development. It recently published the "2013 Agricultural Statistics of Thailand" and has since been updated, enhancing the comprehensiveness of its contents which are now more relevant in a new era of agricultural economics information. It now includes up-to-date and comprehensive outlook information on agricultural economics, including situation and trends from both domestic and foreign sources. Some of the data is collected by the office with the rest of the information acquired from other agencies under the Ministry of Agriculture and Cooperatives, Finance, Defense, Information and Communication Technology and Natural Resources and Environment.

The major sources of agricultural statistics in Thailand include the following:

1. The agricultural census which is conducted by the NSO once every ten years to obtain basic information such as number and area of holding, land use and tenure; planted area of crops, number of livestock; use of fertilizer and pesticides. The Agricultural Census of Thailand was conducted in 1950, 1963, 1978, 1993, and 2003.
2. The Inter-Census Survey of Agriculture which is undertaken every 5 years with the most recent undertaken in 2008.
3. Agricultural surveys which include the following:
    - Crop production surveys undertaken annually by the OQE
    - Livestock and Fisheries Production Surveys
    - Cost of Production Survey
    - Crop Forecasting
    - Remote Sensing and GIS
    - Agricultural farm household socio-economic surveys
    - Agricultural prices

In addition to the above, statistical units are found in many government agencies which collect food and agriculture data from registration or reports for their administrative purposes.

2.2. Animal feed assessments model development

Three animal feed assessment models were used in this study to compare and estimate food-feed production, feed supplies and demand for livestock over the past 10 years.

The **Thai Feed Mill Association is the organization that publishes a report on animal feed demand**, using livestock production figures and estimating feeding requirements. In addition, there is a **DLD feed assessment model** which also estimates feed use and the nutrient requirements of each species/type of livestock. The DLD animal feed assessment model was develop by Department of Livestock Development, Ministry of Agricultural and Cooperatives in collaboration with 10 University and institutions in the Indochinese peninsula region (WTSR, 2010). The **national feed resource and nutritive values database system** was established with the objective of calculating feed balances and composition (surplus/deficit) using

a feed supply approach together with feed demand approach based on animal production systems, herd structure (see Annex 1, 2, 3) and animal nutrient requirements (Annex 5).

DLD animal feed assessment model

The classification and identification of the national livestock feeding systems was undertaken by a task force of animal science researchers, animal nutrition researchers, administration officers, crop science researchers. The system (Figure 1-3) developed by the office of animal nutrition development, Department of Livestock Development, is used to compile, estimate and report feed availability and utilization through the following summary process:

1. Data collected for assessing feed resources and feed balance includes: (a) feed resources derived from crop production (b) green fodder from land use and (c) feed demand or nutrient requirements according to animal production level of each livestock species/type.

2. Annual crop production information are derived from the national agricultural data system and provide input into estimates on the annual feed production, residues, by-products and waste that are available for feeding livestock by using a harvest index and estimated proportion use for animal feed.

3. Harvest indices and extraction ratios of different agricultural crops (Annex 4) are used for estimating crop residues and byproducts (adapted from Chantalakhana and Skunmun (2002) Ramachandra et al., (2007) and Devendra (1993).

4. Additional information on feeds include raw material imports and exports of by- products used for animal feeding, data on pasture areas, pasture productivity. Livestock population data are also obtained.

5. The quantity and quality of available feed resources are derived from crop production data, extraction rates of by-products and co-products used for animal feeding. Then available feed resources are estimated in terms of dry matter, metabolizable energy and crude protein by groups of feed resources. These groups include crop residues, oil seed cake/meals, grains, grain by products, roots and tubers, root and tuber by-products, other by- products, grasses, legume forages, forage trees, other forage.

6. Estimates feed requirements of livestock are generated, based on an understanding of livestock population by production subgroup, their characteristics and nutrient requirements, and these general estimates are translated into annual feed requirements of each type of livestock, categorized in 3 major components (dry matter requirement, ME requirement, DP requirement)

7. The feed balance of the country is calculated by the difference between feed produced, feed imported, feed exported and feed required (Table 21). This leads to estimates of feed surplus/deficit in terms of quantity (DM) and quality (ME and DP).

9. The annual production of compound and concentrate feeds for specific species and their underlining raw material requirements are derived thus quantifying feed resources used in industrial intensive livestock production.

3. Livestock and aquaculture profile and trends

3.1 Growth of livestock and aquaculture production

Thailand is one of the world largest food producing and exporting countries with a GDP of US$ 382.46 billion in 2012 and a population of 64.6 million in 2012 (NESDB, 2013). The agricultural sector (accounting for around 24,118,000 farmers) and livestock (total 3,630,725 families) respectively account for 12.2% and 2.5% of GDP (Sommart et al., 2013).

The major livestock species are chicken, swine, dairy cattle, beef cattle with goat and sheep only a very minor composition of national stocks (Table 1). Broiler products (commercial chicken cuts) are largely exported while other non-ruminant species and ruminant are produced for domestic consumption, supporting a small scale trading sector. Commercialized swine and chicken populations have demonstrated the fastest growth, rising over the past 10 years from 6.70 to 10.98 million heads for swine and 228.76 to 384.18 million numbers for chicken. Such rapid growth was prompted by escalating domestic and global demand for competitively priced broiler meat and products (Figure 1).

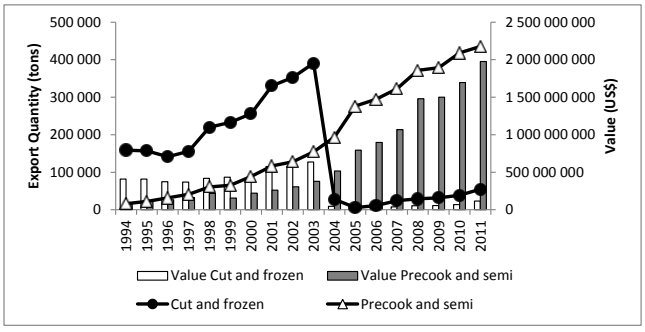

Figure 1. Poultry export quantity and value from Thailand, 1994-2011 (Source: DLD, 2013)

Ducks, both layer and meat types, increased by nearly 50 percent over the 2002-2012 period from 25.03 to 36.69 million birds. Milk, pork and poultry meat exhibited the highest production and consumption growth rate compared to other products in Thailand (Figure 2). Broiler chicken products are one of Thailand's main export commodities (mainly to Japan, UK, the Netherland and others) while other non-ruminant species (pigmeat) and ruminants are produced mainly for domestic consumption with trade limited because of trade restricting animal diseases such as FMD.

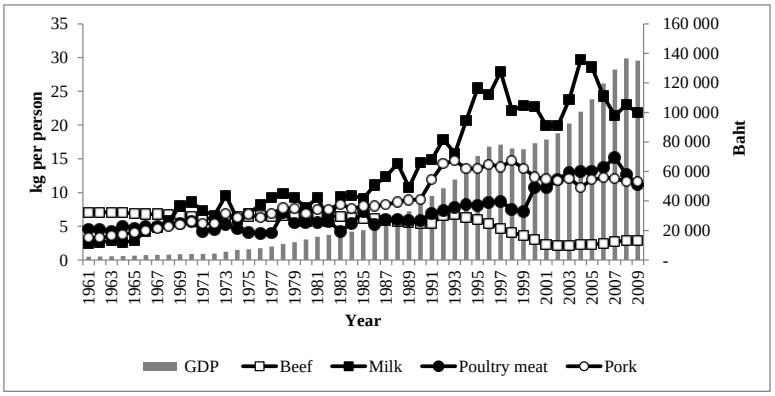

Figure 2. Average annual meat and milk per capita consumption (kg) and per capita GDP (1US$ = 30 Thai Baht) in Thailand – 1961 to 2009 (Source: FAOSTAT, 2013)

Table 1 Livestock population (Million heads) in Thailand

Year	Beef Cattle	Dairy Cattle	Buffalo	Goat	Sheep	Swine	Chicken	Duck
2002	5.55	0.36	1.62	0.18	0.04	6.70	228.76	25.03
2003	5.92	0.38	1.63	0.21	0.04	7.82	252.72	23.80
2004	6.67	0.41	1.49	0.25	0.05	6.29	179.74	15.65
2005	7.80	0.48	1.62	0.34	0.05	8.17	254.20	21.54
2006	8.04	0.41	1.25	0.32	0.05	7.15	184.33	20.84
2007	8.85	0.49	1.58	0.44	0.05	9.30	283.13	24.95
2008	9.11	0.47	1.36	0.37	0.04	7.74	235.60	22.72
2009	8.60	0.48	1.39	0.38	0.04	8.54	281.67	27.57
2010	6.43	0.53	1.19	0.38	0.04	8.35	266.03	29.23
2011	6.58	0.56	1.23	0.43	0.05	9.68	316.53	32.18
2012	6.33	0.58	1.24	0.49	0.04	10.98	384.18	36.69
%change, 2008-2012	-30.52	22.96	-8.82	31.48	-14.55	41.86	63.06	61.49

Source: DLD (2013)

Indigenous livestock (beef cattle, buffaloes, native chicken, goats and pigs) are mainly kept in low input production systems (Annex 1). The most important of the ruminant species in Thailand are beef cattle which include native Thai cattle, crossbred cattle and a small number of purebred beef type cattle (Table 1, 2). Over the last 5 years, beef cattle numbers have fluctuated, but in general witnessed a decline of 30%. This contrasts to the number of dairy cattle which increased approximately 23% percent over the 2008-2012 period, from 0.47 to 0.58 million head. The number of buffalo decreased from 1.62 million in 2002 to 1.24 million by 2012 and while goat numbers increased, sheep numbers have continued to decline.

Table 2 Production of cattle (1,000 heads), buffaloes (1,000 heads), swine (1,000 heads), fresh milk (1,000 tons), poultry (1,000 birds) and eggs (1,000 units) in Thailand

Year	Cattle	Milk	Buffaloes	Swine	Broilers	Hen eggs	Native chickens	Meat ducks	Duck egg
2004	1,022	843	238	12,096	694,359	6,555,291	68,423	21,008	1,209,820
2005	1,103	888	235	12,257	817,239	7,811,080	65,883	20,459	1,389,623
2006	1,166	803	231	13,315	849,881	8,553,867	67,390	20,491	1,436,334
2007	1,197	729	225	13,545	879,981	8,989,855	66,845	21,609	1,471,967
2008	1,187	786	222	12,088	920,754	9,425,964	68,620	21,642	1,462,733
2009	1,173	841	219	11,771	917,263	9,617,832	69,748	21,422	1,453,927
2010	1,130	911	216	12,099	970,943	9,786,855	70,806	21,002	1,410,348
2011	1,087	982	210	11,886	994,319	10,024,435	71,488	23,298	1,233,306
2012	1,026	1,022	206	12,828	1,055,127	10,998,333	72,613	23,769	1,182,365
2013	995	1,095	164	13,072	1,103,323	11,148,498	73,705	23,223	1,126,238
%change 2009-2013	-15.17	30.20	-25.11	11.05	20.28	15.91	5.67	8.41	-22.54

Source: OAE (2014)

3.2. Production systems and structural change of livestock

The introduction, over the past 30 years, of intensified modern livestock operations (dominated by contact farming system/companies) has resulted in a decline in the number of back-yard growers and a structural change from extensive to intensive farming system especially for the dairy sector and swine, broiler, layer and duck operations (Annex-2). These operations are characterized by larger herds per farm (Table 3). The average boiler farm size is now 6,000 birds per farm with corporate farms holding over 100,000 broilers. These intensified systems are characterized by closed semi-automatic housing systems which use large fans and water to cooling houses to 28 degree Celsius, thus saving housing and labor costs as well as reducing mortality rates.

Table 3 Structural change of livestock number per farmer (heads) in Thailand

Years	Beef Cattle	Dairy Cattle	Buffaloes	Goats	Sheep	Swine	Broilers	Layers	Ducks
2007	6.65	23.06	4.18	11.51	8.77	27.82	3,507.02	2,841.53	48.51
2008	6.65	24.46	4.82	11.27	10.18	31.80	3,864.01	1,433.77	59.43
2009	8.60	27.13	4.62	10.68	8.26	31.84	6,076.79	1,709.24	63.39
2010	6.21	26.33	4.60	10.35	8.50	41.70	3,232.13	904.45	56.09
2011	4.94	27.20	4.55	10.28	8.36	42.57	3,962.83	959.49	55.11
2012	6.12	28.02	4.47	10.36	8.51	35.47	5,164.43	869.20	57.15
2013	5.89	29.96	4.51	10.56	8.13	45.08	5,782.04	1,962.49	95.86
%change, 2009-2013	-31.51	10.43	-2.38	-1.12	-1.57	41.58	-4.85	14.82	51.22

Source: DLD (2013)

The average farm size for smaller swine operations now includes 45 pigs per farm compared to commercial pig operations which have been also increasing, up to 300 sows (for contact farms) or 2400 sows (for corporate farm) from 100 sows in early 2000s (Poapongsakorn, 2012). The shift to large scale operations is driven by economies of scale in both production and marketing, input procurements and risk management when compared to smaller operations. Thailand expects to continue as an exporter of chicken cuts through the year 2030. However, Thai exporters, recognizing the importance of adding value to export products while being a large net importer of animal feedstuffs (corn, soy bean meal and fish meals), had a strategy on not exporting fresh whole chicken; rather they capitalized on higher value cuts to high value markets. The rapid intensification of poultry and pig production has, however, increasingly raised issues related to environmentally friendly production practices, animal welfare, disease issues and bio-security (e.g. Highly Pathogenic Avian Influenza (HPAI).

The numbers of beef cattle has continued to decrease (down 30%) over the past 10 years, reflecting land use changes which are intensifying food-feed-bio energy crop production. This development has limited livestock grazing areas as well as household labor availability. However, the growth of the dairy cattle population and milk production has witnessed an opposite trend, increased over the past 10 years. The largest number of dairy cattle is in the

central region (with an average of 30 cattle per farm on 3.2 hectare land holdings) with total milk production totaling approximately 967,844 ton per year. By contrast, the annual catch of fresh water fishery production has dramatically decreased recently because of disease such as EMS (early mortality syndrome) (Table 4).

Table 4 Quality (tons) and value (1,000 baht) of fish farms by type of culture in Thailand

Year	Pond culture		Paddy-field culture		Ditch culture		Cage culture		Total	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
2002	266,461	9,899,436	20,602	823,125	4,113	119,478	3,325	145,721	294,501	10,987,761
2003	319,149	11,690,457	31,582	1,139,310	4,296	115,055	6,097	240,620	361,125	13,185,443
2004	455,981	16,799,953	34,967	1,329,305	5,659	185,998	27,102	997,636	523,709	19,312,892
2005	478,121	17,695,488	31,703	1,208,469	4,911	153,197	24,739	1,105,337	539,474	20,162,491
2006	465,307	17,687,421	29,226	1,098,898	4,762	150,069	28,119	1,251,951	527,414	20,188,339
2007	453,666	18,389,638	26,797	1,037,996	11,571	280,580	33,062	1,413,771	525,095	21,121,985
2008	455,643	19,966,319	20,568	829,280	11,929	365,568	34,324	1,716,444	522,463	22,877,610
2009	459,030	20,437,699	20,726	858,548	5,886	197,815	36,238	1,809,392	521,880	23,303,454
2010	429,523	20,229,630	20,923	892,084	6,318	233,077	39,834	2,190,132	496,599	23,544,922
2011	325,995	17,996,187	18,361	890,417	6,407	258,227	33,590	1,903,313	384,353	21,048,144
%change, 2007-2011	-28.14	-2.14	-31.48	-14.22	-44.63	-7.97	1.60	34.63	-26.80	-0.35

Source: OAE (2014)

3.2 Production system and feeding efficiency

The feeding efficiency of livestock in systems in Thailand differs depending on the animal species/ type, and the feeding system (Annex-1). Feed conversion ratios can be used to estimate compound or concentrate livestock feed requirements, especially for non-ruminant species such as pig, poultry and fish (Annex-3; Table 5,6). However, ruminant feeding systems are largely reliant on local agro-industrial by-products as well as the natural grasses found in the traditional crop-rice-livestock-based mixed farming systems. The majority, or 95%, of extensive beef production systems use no cereal grain or concentrate feed supplements. However, in the case of beef-dairy cattle, a shortage of feed, both in terms of quantity and quality, is a major constraint and is expected to pose larger obstacles as farm sizes increase. The shortage of high quality roughage forces dairy farmers to use high concentrate supplements (Annex-2.8) combined with rice straw, crop residues, agro-industrial co-products and/or low quality roughage. This results in low feed intake, poor digestibility, energy utilization and thus low production efficiency as well as air and water environmental stress (e.g. N, P and enteric methane emissions).

Table 5 Estimate compound feed productions (tons), livestock population (heads) and feeding rate (kg/head/year) in Thailand compared between 2002 and 2012

Animal/Types	Year 2002			Year 2012		
	Compound Feed	Livestock	Feeding rate	Compound Feed	Livestock	Feeding rate
1. Broiler	3,923,700	957,000,000	4.10	5,026,450	1,235,000,000	4.07
2. Broiler parent stock	555,300	12,340,000	45.00	691,992	13,730,000	50.40
3. Layer pullets and chicks	606,017	27,970,000	21.67	794,950	36,690,000	21.67
4. Layer hens	1,296,000	32,400,000	40.00	1,840,000	46,000,000	40.00
5. Layer parent stock	21,960	488,000	45.00	26,800	670,000	40.00
6. Finishing pig	2,932,300	9,940,000	295.00	4,336,500	14,700,000	295.00
7. Breeder pig	660,300	710,000	930.00	855,600	920,000	930.00
8. Meat ducks	159,600	19,000,000	8.40	252,000	30,000,000	8.40
9. Layer ducks	97,500	1,500,000	65.00	169,000	2,600,000	65.00
10. Breeder duck	14,600	200,000	73.00	21,900	300,000	73.00
11. Dairy cattle	405,150	370,000	1,095.00	591,300	360,000	1,642.00
12. Shrimp(tons)	560,000	280,000	2.00	375,000	250,000	1.5
13. Fish	262,500	-	-	507,048	300,000	1.69
Total	**11,494,927**	**1,061,828,000**	**-**	**15,488,540**	**1,381,520,000**	**-**
%change				**34.74**	**30.11**	-

Source: Thailand Feed Mill Association (2002, 2012)

Table 6 Major feedstuffs used in compound feed production (ton) by using demand approach in Thailand compared between year 2002 and 2012

Animal/types	Year 2002				Year 2012			
	Fish meal	Soybean meals	Corn	Broken Rice	Fish meal	Soybean meals	Corn	Broken Rice
1. Broiler	117,711	1,177,110	2,432,694	-	150,794	1,507,935	3,116,399	-
2. Broiler parent stock	16,659	138,825	333,180	-	20,760	172,998	415,195	-
3. Layer pullets and chicks	18,181	151,504	363,610	-	23,849	198,738	476,970	-
4. Layer hens	64,800	324,000	712,800	-	92,000	460,000	1,012,000	-
5. Layer parent stock	659	5,490	13,176	-	804	6,700	16,080	-
6. Finishing pig	87,969	586,460	733,075	586,460	130,095	867,300	1,084,125	867,300
7. Breeder pig	33,015	132,060	-	297,135	42,780	171,120	-	385,020
8. Meat ducks	9,576	31,920	23,940	55,860	15,120	50,400	37,800	88,200
9. Layer ducks	7,800	14,625		39,000	13,520	25,350	-	67,600
10. Breeder duck	876	4,380	1,460	6,570	1,314	6,570	2,190	9,855
11. Dairy cattle	-	20,258	60,773	-	-	29,565	88,695	-
12. Shrimp	196,000	67,200	-	-	37,500	75,000	-	-
13. Fish	52,500	78,750	78,750	-	50,705	152,114	152,114	-
Total	**605,746**	**2,732,582**	**4,753,458**	**985,025**	**579,241**	**3,723,789**	**6,401,568**	**1,417,975**
%change2002-2012					**-4.37**	**36.27**	**34.67**	**43.95**

Source: Thailand Feed Mill Association (2002, 2012)

4. Growth and structural change in food-feed production

4.1. Industrial crop and domestic grain production trends

Thailand, as the so-called "kitchen of the world", is located in a tropical and monsoon region with agricultural production systems, supported by a number of plantations which produce human and animal food. It is also one of the world's largest rice and cassava exporters.

Major crops produced include rice, maize/corn grain, cassava, sugar cane, oil palm, soybeans, coconuts and rubber which are for human consumption/use with crop by-products and wastes used for livestock production (Annex 7-11). The land used for rice (11.2%), maize (6.2%), rubber (28.5%), cassava (13.0%) and oil palm (15.8%), sugar cane (32.7%) has increased (Figure 6), accompanied over the past 10 years by a small increase of yield per planting area. Conversely, the planting areas of soybeans (-62.3%) and coconut (-12.6%) has decreased dramatically because of market price competition for second crop rice. In addition, the structure of crop production, especially land use for sugarcane, cassava and para rubber, has also shifted from upland to un-irrigated rice fields or other lower-yielding crops. Land use changes have also occurred because of the competition between food and energy crops. Cassava, sugarcane, oil palm, para rubber production has increased acreage and production due to the world food and energy demand in the past 10 year.

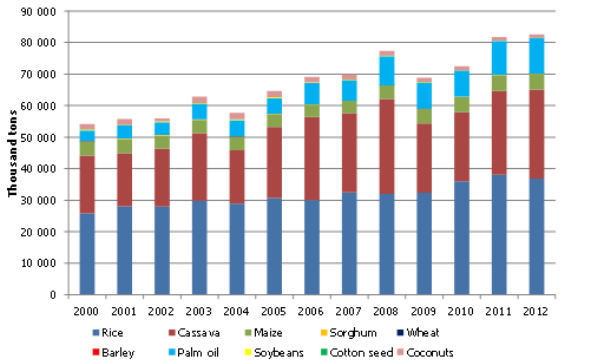

Figure 6: Changes in cereals and oilseed crop production in Thailand

Source: Office of Agricultural Economics, Department of industrial works

Out of total agricultural land estimated at 23.9 million hectares, rice occupies the largest area, or 10.4 hectares. Total rice production is approximately 39 million tons. Rice production in Thailand follows 2 major systems: the major rice (first crop) which is cultivated in the rainy season occupies 10.4 million hectares (rain fed and irrigated) while the second crop rice, dependent on irrigated areas in the dry season, is cultivated on 2.9 million hectares. The major rice production areas are in the Northeast, the North and the Central parts of the country. In addition to being a major source of human food, rice generates by-products which are used for livestock feed, including rice bran, broken rice, rice straw, rice stove. Rice bran and broken rice are mainly used for swine or poultry feed. Rain-fed rice straw, especially in the Northeast, are abundant after harvest (November to June) and used for grazing cattle, goats and sheep. There is limited commercial collection of products for animal feed, vegetable bedding and mush room culture. The irrigated rice straw is usually burnt right after harvest to expedite the next rice crop.

Others arable land associated with crop production linked to the availability of by-product feed can be classified into 4 categories: paddy lands, field crops lands, orchards and plantation lands, and vegetable gardens. On average, a Thai farmer farms on 4.2 hectares of

land. As indicated, a large proportion of land has been used for cultivating crops, including rice in the low lands Meanwhile, cassava, sugar cane, pineapple, corn are produced in upland areas as are oil palm or para rubber tree while the remaining low fertile land is used for ruminant grazing. For non-ruminants, including broilers, layers, meat ducks and pigs, feed availability is linked to commercial compound feed manufactured by feed factories and the main feed ingredients include corn, soybean and fishmeal, cassava and rice bran. Thailand is a major importer of soybean meal as a feed. Meanwhile feed and roughages for ruminants are deficit in the dry season.

In addition to rice, the above 7 major crops provide additional sources of human food, exports while playing important roles as major sources of animal feeds. The feed benefits of these crops are generated by residues and by-products which are used for animal feeding in different forms (Table 7, 8).

Table 7 Feed production, import, export and supply of major feedstuffs used in compound feed production (tons) in Thailand year 2002 and 2012

Feed	Year 2002				Year 2012			
	Production*	Import	Export	Supply**	Production*	Import	Export	Supply**
Fish meal	475,000	19,600	0	494,600	492,000	17,900	0	509,900
Soybean meals	202,800	2,945,620	0	3,148,420	66,300	4,468,600	0	4,534,900
Corn	4,259,000	0	10	4,258,990	4,948,000	197,000	1,224,000	3,921,000
Broken Rice	839,760	0	0	839,760	1,140,000	0	0	1,140,000
Rice bran	3,079,120	0	400	3,078,720	4,180,000	600	3,700	4,176,900
Cassava chip	6,885,517	0	1,369,000	5,516,517	12,339,069	0	4,612,000	7,727,069
Cassava pulp	5,060,400	0	0	5,060,400	9,068,400	0	610,000	8,458,400
Palm kernel meal	3,320,830	0	0	3,320,830	9,427,140	58,500	0	9,485,640
Total	24,122,427	2,965,220	1,369,410	25,718,237	41,660,909	4,742,600	6,449,700	39,953,809

*Extraction rate Soybean meals = 0.78%, Broken Rice = 0.03%, Rice bran = 0.11%, Cassava chip = 0.4082%, Cassava pulp = 0.3%, Palm nut and kernel meal = 0.83%

**Supply = (production + import –export)

Table 8 Feed balances (demand/supply) of major feedstuffs used in compound feed production (ton) in Thailand year 2002 and 2012

Animal/types	Demand Year 2002				Demand Year 2012			
	Fish meal	Soybean meals	Corn	Broken Rice	Fish meal	Soybean meals	Corn	Broken Rice
1. Broiler	117,711	1,177,110	2,432,694	-	150,794	1,507,935	3,116,399	-
2. Broiler parent stock	16,659	138,825	333,180	-	20,760	172,998	415,195	-
3. Layer pullets and chicks	18,181	151,504	363,610	-	23,849	198,738	476,970	-
4. Layer hens	64,800	324,000	712,800	-	92,000	460,000	1,012,000	-
5. Layer parent stock	659	5,490	13,176	-	804	6,700	16,080	-
6. Finishing pig	87,969	586,460	733,075	586,460	130,095	867,300	1,084,125	867,300
7. Breeder pig	33,015	132,060	-	297,135	42,780	171,120	-	385,020
8. Meat ducks	9,576	31,920	23,940	55,860	15,120	50,400	37,800	88,200

9. Layer ducks	7,800	14,625	-	39,000	13,520	25,350	-	67,600
10. Breeder duck	876	4,380	1,460	6,570	1,314	6,570	2,190	9,855
11. Dairy cattle	-	20,258	60,773	-	-	29,565	88,695	-
12. Shrimp	196,000	67,200	-	-	37,500	75,000	-	-
13. Fish	52,500	78,750	78,750	-	50,705	152,114	152,114	-
Feed demand	**605,746**	**2,732,582**	**4,753,458**	**985,025**	**579,241**	**3,723,789**	**6,401,568**	**1,417,975**
Feed supply								
Fish meal	494,600	-	-	-	509,900	-	-	-
Soybean meal	-	3,148,420	-	-	-	4,534,900	-	-
Corn	-	-	4,258,990	-	-	-	3,921,000	-
Broken rice	-	-	-	839,760	-	-	-	1,140,000
Balance (tons)	**-111,146**	**+415,838**	**-494,468**	**-145,265**	**-69,341**	**+811,111**	**-2,480,568**	**-277,975**
Balance (%)	**-18.3**	**+15.2**	**-10.4**	**-14.7**	**-12.0**	**+21.8**	**-38.7**	**-19.6**

Source: Thailand Feed Mill Association (2002, 2012)

4.2. Agro-industrial co-products and available feed resources

The classification of available feed resources in Thailand in accordance with the FAO guideline (FAO, 2012) can be described as follows.

4.2.1. Crop residues.

Crop residues are a major source of livestock feeds in Thailand for ruminants. Crop production areas and productivity are highly associated with the annual yield of their by-products and residues (Annex-4). Major crop residues for Thailand are derived from rice, corn, cassava, sugar cane, oil palm, soybeans, coconuts and pineapples. Some crops provide feed ingredients directly to livestock such as corn and cassava. Many crops generate more than one product and by-products, such as soybeans that provide the soybean meal used in non-ruminant feeds while supplying soybean hull and stems used in ruminant feeds. The major crop residues are rice straw and stove derived from rice harvesting, and sugar cane tops and corn stove. Cassava leaves and palm oil fond and residues are also sources for animal feed. Due to a lack of data, it is difficult to accurately estimate the quantity of crop residues used in livestock feeding.

4.2.2. Oil seed meals

Oilseed meals are agro-industrial by-products derived from the processing of oil crop production. However, there is a decreasing area of oil plants (soybeans, cotton and coconuts) due to price competition with the second rice crop, as well as para rubber trees, sugarcane and cassava. Thus, increasingly, protein as a domestically produced feed source is not sufficient and, in the context of rapidly growing non-ruminant production, Thailand has been obliged to increase imports of oilseed meal as a protein feed source, mainly for broiler and swine production (Table 9) while still remaining a net exporter of feed products (Table 10).

Table 9 Import quantity of main feed products in Thailand (1,000 tons)

Feed Import	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	**%change**
Maize/corn	-	7.9	75.8	58.9	174	150	425	292	367	196	197	**> 500**
Soybean	1,529	1,690	1,436	1,608	1,395	1,541	1,723	1,535	1,819	1,994	2,120	**38.65**
Soybean meal	1,753	1,918	1,262	1,881	2,178	2,105	2,194	2,077	2,616	2,399	2,815	**60.58**
Oil seed cake	295	253	264	314	413	451	561	698	603	555	562	**90.51**

Cotton seed meal	-	-	-	-	0.1	-	0.3	< 0.01	0.8	1.4	1.0	**> 500**
Palm kernel meal	-	-	8.4	95.8	124	59.4	20.3	55.3	92.9	134.5	58.5	**> 500**
Cereal bran	7.8	10.3	11.7	7.7	2.6	41.9	36.9	55.2	22.6	36.0	63.2	**> 500**
Rice bran	-	-	0.02	0.11	3.08	3.38	0.2	< 0.01	< 0.01	0.2	0.6	**> 500**
Wheat bran	2.7	5.1	-	-	5.3	7.2	4.5	5.2	12.9	12.6	4.7	**74.07**
Vegetable residue	0.5	0.3	0.4	0.7	2.0	0.8	0.6	4.7	11.0	20.6	13.7	**> 500**
Beet pulp-Bagasse	-	0.1	0.6	0.3	0.5	0.8	0.5	0.5	0.7	1.2	1.2	**> 500**
Molasses	-	-	-	0.1	0.1	5.7	9.6	20.1	157.6	87.4	21.5	**> 500**
Fish meal and flours	19.6	20.5	21.4	23.4	13.3	19.6	13.0	16.8	13.3	15.5	17.9	**-12.68**
Total	**3,607**	**3,905**	**3,080**	**3,990**	**4,312**	**4,386**	**4,989**	**4,760**	**5,717**	**5,453**	**5,876**	**50.47**

Source: OAE (2014)

Table 10 Export quantity of main feed products in Thailand (1,000 tons)

Feed exports	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	**%change**
Maize/corn	< 0.01	137.2	872	56.9	250	90.8	340	842	393	319	1,224	**> 500**
Cassava chip	1,369	1,812	2,806	2,773	3,930	2,680	1,202	4,024	4,117	3,604	4,612	**236.89**
Cassava pellet	1,535	1,860	2,213	258	393	1,811	1,647	332	156	36.7	84.2	**-94.51**
Cassava pulp	-	61.6	194	320	316	407	332	435	537	422	610	**> 500**
Kapok meal	0.02	< 0.01	< 0.01	< 0.01	0.01	< 0.01	2.1	7.6	10.5	32.1	45.9	**> 500**
Cereal bran	19.7	23.4	28.6	28.3	25.1	29.8	49.2	45.1	51	36.4	15.1	**-23.35**
Rice bran	0.4	0.3	2.6	0.4	0.3	3.1	0.8	2.0	0.9	1.0	3.7	**> 500**
Wheat bran	< 0.01	0.4	-	0.1	-	< 0.01	-	1.4	0.1	0.1	0.4	**> 500**
Vegetable residue	61.0	66.1	56.7	55.6	90.2	58.3	39.1	44.4	45.5	38.7	34.8	**-42.95**
Beet pulp-Bagasse	1.8	3.1	6.6	6.8	6.6	9.8	11.7	9.1	10.2	11.1	11.9	**> 500**
Molasses	1,358	1,328	1,500	1,159	502	549	787	444	237	397	980	**-27.84**
Compound feeds	186	226	262	282	321	270	300	313	342	376	374	**101.08**
Total	**4,531**	**5,518**	**7,942**	**4,941**	**5,834**	**5,909**	**4,711**	**6,500**	**5,900**	**5,274**	**7,996**	**76.47**

Source: OAE (2014)

4.2.3. Cereal and grain by products

Rice by- products including rice bran and broken rice are an important feed source (Table 14). However, because of robust demand, grain by-products have been increasingly imported including brewery by-products, DDGS, wheat bran and corn by-products (Table 14).

4.2.4. Grains

Corn is the major grain used in Thai feed formulation with annual feed use estimated at approximately 6.5 million tons (Table 11). The largest quantity of corn is used in broilers, layers, ducks and pigs feed formulation. Some corn and corn products for livestock feeding have been imported.

Table 11 Major feedstuffs used in compound feed production (ton) by using demand approach in Thailand compared between year 2002 and 2012

Animal/types	Year 2002				Year 2012			
	Fish meal	Soybean meals	Corn	Broken Rice	Fish meal	Soybean meals	Corn	Broken Rice
1. Broiler	117,711	1,177,110	2,432,694	-	150,794	1,507,935	3,116,399	-
2. Broiler parent stock	16,659	138,825	333,180	-	20,760	172,998	415,195	-
3. Layer pullets and chicks	18,181	151,504	363,610	-	23,849	198,738	476,970	-
4. Layer hens	64,800	324,000	712,800	-	92,000	460,000	1,012,000	-

5. Layer parent stock	659	5,490	13,176	-	804	6,700	16,080	-
6. Finishing pig	87,969	586,460	733,075	586,460	130,095	867,300	1,084,125	867,300
7. Breeder pig	33,015	132,060	-	297,135	42,780	171,120	-	385,020
8. Meat ducks	9,576	31,920	23,940	55,860	15,120	50,400	37,800	88,200
9. Layer ducks	7,800	14,625		39,000	13,520	25,350	-	67,600
10. Breeder duck	876	4,380	1,460	6,570	1,314	6,570	2,190	9,855
11. Dairy cattle	-	20,258	60,773	-	-	29,565	88,695	-
12. Shrimp	196,000	67,200	-	-	37,500	75,000	-	-
13. Fish	52,500	78,750	78,750	-	50,705	152,114	152,114	-
Total	**605,746**	**2,732,582**	**4,753,458**	**985,025**	**579,241**	**3,723,789**	**6,401,568**	**1,417,975**
%change2002-2012					**-4.37**	**36.27**	**34.67**	**43.95**

Source: Thailand Feed Mill Association (2002, 2012)

4.2.5. Roots, tubers and other by-products

Globally, Thailand is the largest exporter of cassava. Cassava chip or cassava pulp feeding technologies have been developed and currently 20% of dairy cattle rations include cassava in order to reduce feed costs (Sommart et al., 2000a,b). However, cassava use as a feed is limited due to its low protein content with users required to maintain a mix of 75:25 cassava: soybean meal that allows the replacement of corn grain or broken rice for diets of pig or broilers.

Other crop by-products produce in Thailand are also abundant i.e. corn cobs, baby corn waste, tomato waste, can fruit waste, seafood industry waste, fish processing waste etc. However, formal data on their availability, their productivity and utilization in animal feeding are lacking.

4.2.7. Grasses and forages

Grasses are primary sources of roughage for feeding ruminants in Thailand. Sources of grasses for livestock include natural pastures, communal pastures, roadside grazing, forest grazing, natural grasses under paddy and upland crops, fallow lands and introduced improved pastures. Most dairy farms depend on improved pasture, in addition to crop residues. Buffalo and goats depend on native grasses.

Although Thailand has introduced large numbers of leguminous species with the objective that the availability of protein/nitrogen feed inputs increase, thus benefiting the livestock sector, legumes play a minor role in livestock feeding. The Leucaena (*Leucaena leucocephala*) is an important forage tree in Thailand, grown abundantly in the Central, North and Northeastern of Thailand. Its fresh fodder is used for ruminant feeding, while dry leucaena leaf meal is used in non-ruminant feeds. Other forages such as fresh leaves of many natural forest species are available through forest grazing. Twigs of fruit trees, vegetable by-products and many other crops by-products such as fruit waste (e.g. jackfruit, orange, banana) are rich sources of nutrients and have been commonly used in animal feeding.

4.2.8. Animal by products

An important by-product widely used in intensive non-ruminant feed formulation is fish meal. Annual fish meal production in Thailand was reported at 443,153 tons in 2012 with approximately 75% used as livestock feed. With the Thai Feed Mill Association reporting in 2012 a total use of 578,463 tons of fish meal and protein supplements in livestock feed production, this implies a deficit in fishmeal availability, with imports accounting for more than one third of fish meal consumption. The largest amount of fish meals is used in broilers, pigs, fish and shrimp feeds, respectively (see Table 11)

4.3. Current trends in animal feed industry in Thailand

4.3.1. Trade in feeds and raw materials

Thailand is one of the leading importers of animal feed, with imports rising by more than fifty percent over the past decade, particularly corn and oilseed meals which are key ingredients in the compound feed industry (Table 12). In 2012, over 3 million tons of protein feed were imported; this included soybean meals, oil seed cake/bran and fish meals. Wheat by-products and corn by-products are also regularly imported to respond to energy shortages in non-ruminant feeds.

Table 12 Import quantity of main feed products in Thailand (1,000 tons)

Feed Import	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	**%change**
Maize/corn	-	7.9	75.8	58.9	174	150	425	292	367	196	197	**> 500**
Soybean	1,529	1,690	1,436	1,608	1,395	1,541	1,723	1,535	1,819	1,994	2,120	**38.65**
Soybean meal	1,753	1,918	1,262	1,881	2,178	2,105	2,194	2,077	2,616	2,399	2,815	**60.58**
Oil seed cake	295	253	264	314	413	451	561	698	603	555	562	**90.51**
Cotton seed meal	-	-	-	-	0.1	-	0.3	< 0.01	0.8	1.4	1.0	**> 500**
Palm kernel meal	-	-	8.4	95.8	124	59.4	20.3	55.3	92.9	134.5	58.5	**> 500**
Cereal bran	7.8	10.3	11.7	7.7	2.6	41.9	36.9	55.2	22.6	36.0	63.2	**> 500**
Rice bran	-	-	0.02	0.11	3.08	3.38	0.2	< 0.01	< 0.01	0.2	0.6	**> 500**
Wheat bran	2.7	5.1	-	-	5.3	7.2	4.5	5.2	12.9	12.6	4.7	**74.07**
Vegetable residue	0.5	0.3	0.4	0.7	2.0	0.8	0.6	4.7	11.0	20.6	13.7	**> 500**
Beet pulp-Bagasse	-	0.1	0.6	0.3	0.5	0.8	0.5	0.5	0.7	1.2	1.2	**> 500**
Molasses	-	-	-	0.1	0.1	5.7	9.6	20.1	157.6	87.4	21.5	**> 500**
Fish meal and flours	19.6	20.5	21.4	23.4	13.3	19.6	13.0	16.8	13.3	15.5	17.9	**-12.68**
Total	**3,607**	**3,905**	**3,080**	**3,990**	**4,312**	**4,386**	**4,989**	**4,760**	**5,717**	**5,453**	**5,876**	**50.47**

Source: OAE (2014)

Interesting enough, Thailand is also an exporter of feed and raw material (e.g. 4,696,000 tons of cassava chips/pellets, 1,224,000 of corn and 374,00 tons of compound feed in 2012; Table 15). These shipments are likely a result of regional investments by Thai feed companies in neighboring countries, thus prompting some re-exports of raw feed materials and compound feed to their livestock/feeding operations in Cambodia, Laos PDR, Vietnam and Myanmar. This reveals the dynamism of the regional feed import/export business where Thai feed operations have a major presence in South East Asia. As the result of a long history of investments in the feed industry in Thailand and subsequent cross-border investments in the

region, Thailand has become a hub of feed industry characterized by raw material imports and re-exports in the form of value added compound feeds.

4.3.2. Growth of the feed industry

As a rapidly growing producer and exporter of poultry meat over the past decades, the compound feed industry in Thailand has witnessed very fast growth (Table 13). The Thailand Feed Mill Association includes 51 members that commercially produce compound/concentrate feed. They include such companies as Charoen Pokphand Food Public Co., CPF Food Products Co; Leamthong Agri products Co, Betagro Public Co., etc. The Association publishes data on national compound feed production with national estimates shown in table 16, 17. The total quantity of compound feed produced in Thailand increased approximately 26% over the past 5 years to 15.5 million tons and it is allocated among the major 13 livestock species, but mainly broilers (33%), layer hens (12%), finishing pigs (28%) and other species included fish and shrimp.

Table 13 Commercial compound feed production (tons) estimated by using demand approach in Thailand

Year	Cattle	Swine	Chicken	Duck	Shrimp	Fish	Total
2002	405,150	3,592,600	6,402,977	271,700	560,000	262,500	11,494,927
2003	405,150	3,620,500	4,878,401	200,490	544,000	355,500	10,004,041
2004	427,050	3,923,900	5,109,173	229,340	492,000	402,000	10,583,463
2005	383,250	4,431,450	6,099,378	348,448	582,900	391,180	12,236,606
2006	344,925	4,814,250	5,886,877	359,258	883,000	575,085	12,863,395
2007	355,875	4,050,250	6,398,357	359,258	883,000	575,085	12,621,825
2008	474,500	3,753,000	6,354,165	403,900	720,000	557,000	12,262,565
2009	474,500	4,035,500	6,644,451	403,900	720,000	571,860	12,850,211
2010	498,225	4,623,900	7,366,331	436,400	800,000	600,453	14,325,309
2011	574,875	4,881,700	8,110,618	442,900	810,000	630,476	15,450,569
2012	591,300	5,192,100	8,380,192	442,900	375,000	507,048	15,488,540
%change, 2008-2012	24.62	38.35	31.89	9.66	-47.92	-8.97	26.31

Sources: Thailand Feed Mill Association (2013)

Over the past 10 years, the increase in demand for soybeans, corn and broken rice has grown 36, 34 and 44%, respectively. Meanwhile, in aggregate, the estimated feed supply (feed production+ import – export) increased dramatically (+55%) over the past 10 years (Table 14). Table 20 provides information generated by the Thai Feed Mill Association model on the major feedstuffs used in feed manufacturing. Between 2002 and 2012, shifts in the use of major raw materials used in industrial feed production includes fish meal (-4.37%), soybean meal (36.27%), maize/corn (34.67%) and broken rice (43.95%). Thailand, in general, is relatively sufficient in major feed ingredients for livestock except for protein feed requirements.

Table 14 Feed production, import, export and supply of major feedstuffs used in compound feed production (tons) in Thailand year 2002 and 2012

Feed	Year 2002				Year 2012			
	Production*	Import	Export	Supply**	Production*	Import	Export	Supply**
Fish meal	475,000	19,600	0	494,600	492,000	17,900	0	509,900
Soybean meals	202,800	2,945,620	0	3,148,420	66,300	4,468,600	0	4,534,900
Corn	4,259,000	0	10	4,258,990	4,948,000	197,000	1,224,000	3,921,000
Broken Rice	839,760	0	0	839,760	1,140,000	0	0	1,140,000
Rice bran	3,079,120	0	400	3,078,720	4,180,000	600	3,700	4,176,900
Cassava chip	6,885,517	0	1,369,000	5,516,517	12,339,069	0	4,612,000	7,727,069
Cassava pulp	5,060,400	0	0	5,060,400	9,068,400	0	610,000	8,458,400
Palm kernel meal	3,320,830	0	0	3,320,830	9,427,140	58,500	0	9,485,640
Total	24,122,427	2,965,220	1,369,410	25,718,237	41,660,909	4,742,600	6,449,700	39,953,809

*Extraction rate Soybean meals = 0.78%, Broken Rice = 0.03%, Rice bran = 0.11%, Cassava chip = 0.4082%, Cassava pulp = 0.3%, Palm nut and kernel meal = 0.83%

**Supply = (production + import –export)

Each species of livestock requires different types of raw materials in line with their specific nutrient requirements for optimal growth. Some of the feed ration considerations reveal that rice bran is used more in pig and duck feed while fishmeal, soybean meal and corn are essential components in broiler feed. It should be noted that shrimp and fish feed have become an emerging feed industry requiring increasing high quality raw materials. As shown in Table 15, a large quantity of fish meal and soybean meal had been incorporated in fish and shrimp feed.

Available feed resources and their composition were calculated by using the DLD feed assessment model, a supply-side approach toward estimating feed requirements. The results indicated that the annual feed availability in Thailand in 2012 totaled 51,5 million tons, derived mainly from crop residues (32.5%), grain by-products (8.3%), roots (28.8%) and by-products (3.78%), grains (6.3%). Crop residues constitute the major sources of dry matter (DM) and metabolizable energy (ME), accounting for 32.5% and 35.8% of total supplies, respectively, while cassava was the largest source, or 41%, of energy feed sources. Figure 7 depicts information on dry matter availability by feed sources categories. In term of DM availability, crop residues were the major contributors (32.51 %), followed by roots (28.84 %) and grazing (19.23 %). Figure 8 highlights feed availability in term metabolizable energy (ME).

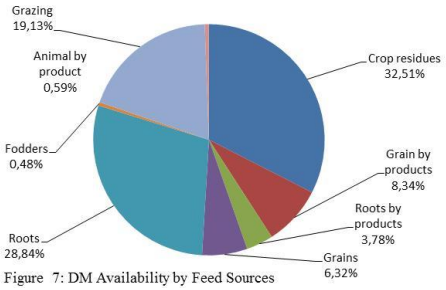

Figure 7: DM Availability by Feed Sources

Roots (cassava) provided the largest quantity of ME (41 %) for Thai livestock followed by crop residues (26%). In term of DP, crop by-products i.e. soybean meals, coconut meals, palm kernel cake/meals, were the main contributors (36 %), followed by grain by-products and grazing. In terms of DM demand, cattle (Native, Crossbreds and Beef) required the largest

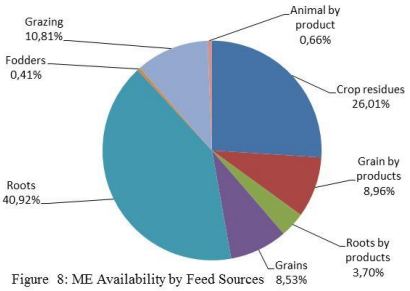

Figure 8: ME Availability by Feed Sources

quantity (43.5 %), followed by chicken (23 %). Chicken (Native, Broilers and Layers) required the largest quantity of ME (34%), followed by cattle (31 %) and pigs (22 %). In terms of CP, chicken and pigs required the largest quantity of 40% and 23.4 %, respectively as illustrated in Figure 9.

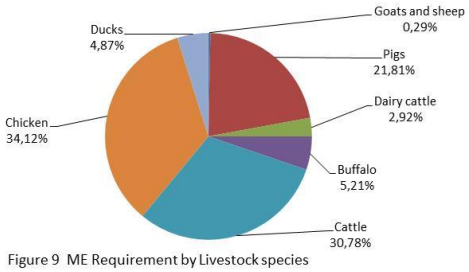

Figure 9 ME Requirement by Livestock species

4.3.3. Feed balance, feed surplus and deficit

The national feed balance, e.g. major feedstuffs demand for compound feed production, is presented in Table 15. The data reveals feed deficits for corn (-38.7%), broken rice (-19.6%), and fish meal (-12.0%). However, the estimate of feed balances using the DLD feed assessment model indicate a surplus of feed availability in terms of DM (+26.9 %), CP (+9.3 %) and ME (35.7 %). Crops, crop by-products and co-products (crop residues, grain by-products, roots, roots by-products, grains, crop by products) were major sources of feed DM (74 %), DP (51.4 %) and ME (82.3 %). Imported feeds (soybean meals and protein supplements) supplied significant quantity of digestible protein (31.81 %).

Table 15 Feed balances (demand/supply) of major feedstuffs used in compound feed production (ton) in Thailand year 2002 and 2012

Animal/types	Demand Year 2002				Demand Year 2012			
	Fish meal	Soybean meals	Corn	Broken Rice	Fish meal	Soybean meals	Corn	Broken Rice
1. Broiler	117,711	1,177,110	2,432,694	-	150,794	1,507,935	3,116,399	-
2. Broiler parent stock	16,659	138,825	333,180	-	20,760	172,998	415,195	-
3. Layer pullets and chicks	18,181	151,504	363,610	-	23,849	198,738	476,970	-
4. Layer hens	64,800	324,000	712,800	-	92,000	460,000	1,012,000	-
5. Layer parent stock	659	5,490	13,176	-	804	6,700	16,080	-
6. Finishing pig	87,969	586,460	733,075	586,460	130,095	867,300	1,084,125	867,300
7. Breeder pig	33,015	132,060	-	297,135	42,780	171,120	-	385,020
8. Meat ducks	9,576	31,920	23,940	55,860	15,120	50,400	37,800	88,200
9. Layer ducks	7,800	14,625	-	39,000	13,520	25,350	-	67,600
10. Breeder duck	876	4,380	1,460	6,570	1,314	6,570	2,190	9,855
11. Dairy cattle	-	20,258	60,773	-	-	29,565	88,695	-
12. Shrimp	196,000	67,200	-	-	37,500	75,000	-	-
13. Fish	52,500	78,750	78,750	-	50,705	152,114	152,114	-
Feed demand	**605,746**	**2,732,582**	**4,753,458**	**985,025**	**579,241**	**3,723,789**	**6,401,568**	**1,417,975**
Feed supply								
Fish meal	494,600	-	-	-	509,900	-	-	-
Soybean meal	-	3,148,420	-	-	-	4,534,900	-	-
Corn	-	-	4,258,990	-	-	-	3,921,000	-
Broken rice	-	-	-	839,760	-	-	-	1,140,000
Balance (tons)	**-111,146**	**+415,838**	**-494,468**	**-145,265**	**-69,341**	**+811,111**	**-2,480,568**	**-277,975**
Balance (%)	**-18.3**	**+15.2**	**-10.4**	**-14.7**	**-12.0**	**+21.8**	**-38.7**	**-19.6**

Source: Thailand Feed Mill Association (2002, 2012)

5. Knowledge gaps and inconsistencies

For Thailand, domestic demand for livestock products will continue to grow, while exports to the region will accelerate in response to population and income growth. It is estimated that feed demand to meet livestock requirements will continue to increase. Our study indicated that energy feed production is sufficient for livestock production demand. However, in addition to producing a large quantity of food and feed, Thailand is importing and will continue to import large quantities of raw materials, especially maize and soybean meal for pig and poultry feed. The usefulness of understanding feed use requirements has been discussed and the variation of information and systematic compiling and disseminating on feed resources use (Table 16) was demonstrated.

Table 16 Compared among three feed demand assessment model of compound feed (1,000 tons) for Livestock in Thailand year 2012

Livestock	Feed demand assessment model					%Difference		
	TMA(1)	OAE(2)	DLD					
			Roughage	Concentrate(3)	Total	(1) vs (2)	(1) vs (3)	(2) vs (3)
1. Goats and sheep	-	-	115	-	115	-	-	-
2. Pigs	5,192	4,264	-	6,236	6,236	18	20	46
3. Dairy cattle	591	949	-	1,926	1,926	60	226	103
4. Buffalo	-	-	3,709	-	3,709	-	-	-
5. Beef cattle	-	-	17,625	-	17,625	-	-	-
6. Chicken	8,380	7,349	-	9,251	9,251	12	10	26
7. Ducks	443	396	-	1,669	1,669	11	277	322
8. Shrimp	375	300	-	-	-	20	-	-
9. Fish	507	551	-	-	-	9	-	-
Grand Total	15,489	13,809	21,449	19,081	40,530	11	23	38

TMA = Thailand Feed Mill Association , OAE = Office of Agricultural Economics, DLD = Department of livestock development

Increased consolidation of the poultry and pig industries are likely to be a key factor influencing food-feed imports which are likely to continue their upward trends. However, ruminant production systems, currently challenged by periodic feed shortages, need to develop increasing linkages to feed production and specialized operations - large farm size (e.g. fattening, milking cows system) to manage operational risk in a low return business. This requires increase adaptive research on food crops affected by climate change and/or agro-industrial co-products such as rice straw, pineapple waste, baby-corn by-products, cassava pulp from starch/bio-ethanol.

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Annexes: 1-14

Annex-1: Main Livestock Feeding Systems in Thailand, 2012

Annex 1.1: Main Livestock Feeding Systems in Thailand, 2012: Beef cattle

Agro-eco-zone	Mixed crop livestock system (MCLS)
	Season (Year-round)
Central, North and Northeast regions	Natural grass and crop residues based feeding systems: All year grazing on paddy and upland crops field after or before harvesting season with provision of crop waste and crop by-product.
Southern	Under plantation grazing with cut and carry and crop residue feeding systems: Grazing under plantation i.e. rubber, palm oil, orchard and roadside with provision of cut and carry fodder grass and fodder tree leaves, palm kernel meal and palm front.

Annex 1.2: Main Livestock Feeding Systems in Thailand, 2012: Buffalo

Agro-eco-zone	Mixed crop livestock system (MCLS)
	Season (Year-round)
Central, North and Northeast regions	Natural grass and crop residues based feeding systems: All year grazing on paddy and upland crops field after or before harvesting season with provision of crop waste and crop by-product.
Southern	Under plantation grazing with cut and carry and crop residue feeding systems: Grazing under plantation i.e. rubber, palm oil, orchard and roadside with provision of cut and carry fodder grass and fodder tree leaves, palm kernel meal and palm fron.

Annex 1.3: Main Livestock Feeding Systems in Thailand, 2012: Dairy cattle

Agro-eco-zone	Intensive system (IPS)
	Season (Year-round)
Central, North, Northeast and South regions	Intensive cut and carry and crop by product systems: Roughage based on intensive improved pasture provides by daily cut and carry systems with equal quantity of high nutrient compound concentrate of 50:50 ratio.

Annex 1.4: Main Livestock Feeding Systems in Thailand, 2012: Pigs

Agro-eco-zone	Intensive system (IPS)
	Season (Year-round)
Central, North, Northeast and South regions	Intensive compound concentrate feeding systems: Under restrict feeding program boar and sows are feeding compound concentrate with the ration of commercial and home mixed of 30:70 ratio.

Annex 1.5: Main Livestock Feeding Systems in Thailand, 2012: Goats and sheep

Type	Region	Mixed crop livestock system (MCLS)	Intensive system (IPS)
		Season (Year-round)	Season (Year-round)

Dairy goats	All		Intensive cut and carry and crop by product systems: Roughage based on intensive improved pasture provides by daily cut and carry systems with equal quantity of high nutrient compound concentrate of 50:50 ratio.
Meat goats	Central, North and North east	Natural grass with cut and carry and crop residues based feeding systems: All year grazing on paddy and upland crops field after or before harvesting season with provision of cut and carry pasture or grazing on improved pasture and supplementary of rop waste, crop by-product and/or concentrate compound feed.	
	Southern	Under plantation grazing with cut and carry and crop residue feeding systems: Grazing under plantation i.e. rubber, palm oil, orchard and roadside with provision of cut and carry fodder grass and fodder tree leaves, palm kernel meal and palm fron.	
Sheep	Central, North and North east	Natural grass with cut and carry and crop residues based feeding systems: All year grazing on paddy and upland crops field after or before harvesting season with provision of cut and carry pasture or grazing on improved pasture and supplementary of crop waste, crop by-product and/or concentrate compound feed.	

Annex- 1.6: Main Livestock Feeding Systems in Thailand, 2012: Poultry

Types	Mixed crop livestock system (MCLS)	Intensive system (IPS)
	Season (Year-round)	Season (Year-round)
Native chicken		
Broilers		
Layers		
Meat ducks		Intensive commercial compound based feeding systems: Under ad lib feeding program commercial compound feeds are used on meat duck feeding 100 %.
Layer ducks		Semi free range and agro-by-product supplementary systems: Smallholders raise free range native chicken by provide some quantity of agro-by-products i.e. rice bran, broken rice, corn, kitchen waste accounted for app. 40 % of their dairy requirement.
Small-holder ducks	Semi free range and commercial compound feed supplementary systems: Smallholders raise free range meat and layer ducks by scavenging in the paddy after rice harvested with daily supplement of commercial compound feeds accounted for app. 40 % of their dairy requirement.	Intensive commercial compound based feeding systems: Under *add libitum* feeding program commercial compound feeds are used on broiler feeding 100 %.
		Intensive compound based feeding systems: Layer feeding program based on commercial compound feeds and home mixed feed with ratio of 50:50.

Annex-2: Livestock herd Structure

Annex-2.1: Herd Structure: Beef cattle

Age groups	Number (head)	Average weight (kg)
1. Native		

Native mature bulls	1,384,080	375-425
Native mature cows	1,028,541	175-250
Native yearly	1,677,776	80-175
Native calves	559,258	16-80
2. Crossbred		
Crossbred mature bulls	470,934	500-550
Crossbred mature cows	566,309	300-425
Crossbred yearly	594,656	100-300
Crossbred calves	198,218	24-100
3. Feedlot	103,332	
Total	6,583,104	

Annex-2.2: Herd Structure: Buffaloes

Age groups	Number (head)	Average weight (kg)
Mature native bulls	362,373	500-550
Mature native cows	614,403	350-440
Yearly native	193,052	90-350
Calves	64,350	24-90
Total	1,234,178	

Annex-2.3: Herd Structure: Dairy cattle

Age groups	Number (head)	Average weight (kg)
Milking cows	215,868	450-650
Dry cows	70,157	550-650
Heifers pregnant	43,174	350-450
Heifer non-pregnant	26,984	280-350
Yearly heifer	70,157	125-280
Calves	113,330	24-125
Total	539,670	

Annex-2.4: Herd Structure: Goats and sheep

Age groups	Number (head)	Average weight (kg)
Dairy goats	33,363	30
Meat goats	394,204	20
Sheep	51,735	30
Total	479,302	

Annex-2.5: Herd Structure: Pigs

Age groups	Number (head)	Average weight (kg)
Native crossbred sows	711,943	120-150
Boars	153,724	150-200

Sows	942,586	150-200
Finishing Weight 20-50 kg	3,046,120	20-50
Finishing Weight 50-80 kg	2,030,746	50-80
Finishing Weight 80-200 kg	1,015,373	80-100
Total	6,092,239	

Annex-2.6: Herd Structure: Poultry

Age groups	Number (head)	Average weight (kg)
Chicken		
Native chicken	76,155,430	1.5-2.5
Broilers	173,869,082	1.5-2.0
Broiler parent stock	14,737,437	2.5-3.5
Layers	49,403,372	1.5-2.0
Layer parent stock	2,371,043	1.5-2.0
Total	316,536,364	
Ducks		
Muscovy (meat) ducks	6,092,135	2.5-3.5
Native meat ducks	986,974	1.4-1.5
Meat ducks	8,949,007	2.5-3.5
Native layer ducks	7,976,123	1.4-1.5
Layer ducks	8,174,988	1.4-1.5
Total	32,179,227	

Annex-2.7: Percent of livestock population by production systems

Livestock types	Mixed crop livestock (%)	Intensive	Total (%)
Beef cattle	99	1	100
Dairy cattle		100	100
Buffalo	100		100
Dairy goat		100	100
Meat goat	100		100
Sheep	100		100
Pigs	20	80	100
Native chicken	100		100
Broilers		100	100
Layers		100	100
Native ducks	100		100
Meat ducks		100	100
Layer ducks	50	50	100

Annex-2.8: Average daily concentrate feed allowances

Livestock types	Intensive systems	Total

	Home-made concentrate (kg DM/day)	Compound feed (kg DM/day)	(kg DM/day
Goats and sheep			
Dairy goats		0.6	0.6
Pigs			
Native crossbred fattening	1.5		1.5
Boars		5.35	5.35
Sows and piglets		5.35	5.35
Finishing Weight 20-50 kg	0.5		0.5
Finishing Weight 50-80 kg	1		1
Finishing Weight 80-200 kg	1.5		1.5
Dairy cattle			0
Milking cows		6.2	6.2
Dry cows		7.2	7.2
Heifers pregnant		5	5
Heifer non-pregnant		4	4
Yearly heifer		3.5	3.5
Calves		1	1
Feedlot	7.5		7.5
Chicken			
Broilers		0.07-.12	0.07-.12
Broiler parent stock		0.15	0.15
Layers		0.12	0.12
Layer parent stock		0.12	0.12
Ducks			
Muscovy (meat) ducks		0.15	0.15
Native meat ducks		0.12	0.12
Meat ducks		0.15	0.15
Native layer ducks		0.13	0.13
Layer ducks		0.13	0.13

Annex-2.9: Raw material used in livestock feeding (%DM)

Raw materials	Mixed Crop-Livestock Systems	Intensive Systems		Total (%)
	Roughage	Home-made concentrate	Compound feed	
Rice straw	12.88			12.88
Corn stem and aerial parts	1.26			1.26
Cassava leaf	0.26			0.26
Molasses			3.50	3.50
Sugar cane top	0.52			0.52

Bagasse	1.55			1.55
Palm kernel cake & meal with coat			3.83	3.83
Palm kernel cake & meal without coat			3.76	3.76
Palm fruit press			3.76	3.76
Broken rice		2.73		2.73
Rice bran		2.70	2.70	5.40
Corn husk	0.20			0.20
Cassava residue			2.50	2.50
Cassava pulp ethanol residue			2.50	2.50
Corn grain		3.16	3.16	6.32
Cassava chip			28.83	28.83
Cultivated pasture	0.48			0.48
Communal pasture	19.13			19.13
Fish meals			0.59	0.59
Total	36.28	8.59	55.13	100.00

Annex- 3: Summary of livestock production characteristics and feed requirement

Livestock Types	Characteristics	Description
1. Beef Cattle		
1.1 Native cattle		
	Production Systems	Mixed crop-livestock systems (MCLS)
	Feeding Systems	Subsystem I: Natural grass and crop residues based feeding systems.
		Subsystem II: Under plantation grazing with cut and carry and crop residue feeding systems.
	Population, head	4,649,655
	Breeds	Thai Native
	Calf crop, %/year	40-45
	Calving interval, year	1.5
	Calf mortality, %	5-15
	Cow replacement rate, %	6-7
	Age at replacement, year	15-16
	Land use per Animal Unit, ha	.15-.20
	Animal per family, head	1-4
	Average body weight	
	Birth weight, kg	16-18

	Weaning weight, kg	80-100
	Mature cows, kg	175-250
	Mature bulls, kg	375-425
	ADG, kg	0.2-0.24
	DM Requirement, kg/day	2.90-9.10
	ME Requirement, MJ/day	20.50-66.11
	DP Requirement, g/day	208-307
1.2 Beef cattle		
	Production Systems	Mixed crop-livestock systems (MCLS)
	Feeding Systems	Natural grass with cut and carry and crop residues based feeding systems.
		Under plantation grazing with cut and carry and crop residue feeding systems.
	Population, head	1,830,117
	Breeds	Crossbred Native-Brahman
	Calf crop, %/year	40-45
	Calving interval, year	1.5
	Calf mortality, %	5-15
	Cow replacement rate, %	6-7
	Age at replacement, year	15-16
	Land use per Animal Unit, ha	.15-.20
	Animal per family, head	1-4
	Average body weight	
	Birth weight, kg	24-32
	Weaning weight, kg	100-150
	Mature cows, kg	300-425
	Mature bulls, kg	500-550
	ADG, kg	.30-.35
	DM Requirement, kg/day	3.10-11.40
	ME Requirement, MJ/day	25.6-84.10
	DP Requirement, g/day	262-460
1.3 Fattening cattle		
	Production Systems	Intensive systems
	Feeding Systems	Intensive confine feedlot feeding systems.
	Population, head	103,332
	Breeds	Crossbred Brahman-Europe Beef
	Market weight, kg	500-650
	Market age, year	1.5-3.0

	ADG, kg	1.0-1.3
	FCR	6.5-8.5
	DM Requirement, kg/day	9.2
	ME Requirement, MJ/day	81.79
	DP Requirement, g/day	875
2. Dairy cattle		
	Production Systems	Intensive Production Systems (IPS)
	Feeding Systems	Intensive cut and carry and crop by product systems.
	Population, head	539,670
	Breeds	Crossbred Holstein Freisian
	Average cattle per farms, head	
	Total cattle	38 (100 %)
	Milking cows	15 (40 %)
	Dry cows	5 (13 %)
	Heifer, pregnant	3 (8 %)
	Heifer, non-pregnant	2 (5 %)
	Yearly	5 (13 %)
	Calves	8 (21 %)
	Average milk yield, kg/day	12.30
	Milk quality	
	Average Bacterial Count, X 1,000 col/ml	220
	Somatic Cell Count, X 1,000 cell/ml	328
	Fat, %	3.75
	Protein, %	3.01
	Total solid, %	12.35
	SNF, %	8.6
	Pasture land, ha/farm	0.75
	Roughage sources	
	Young corn stem, %	43.47
	Fresh grass, %	32.60
	Corn husk, %	21.74
	Straw, %	2.17
	DM Requirement, kg/day	
	Milking cows	12.40
	Dry cows	14.40
	Heifer pregnant	11.30
	Heifer non-pregnant	9.60
	Yearly heifer	7.00
	Calves	3.10

	ME Requirement, MJ/d	
	Milking cows	64.00
	Dry cows	58.58
	Heifer pregnant	84.94
	Heifer non-pregnant	87.86
	Yearly heifer	64.02
	Calves	28.03
	DP Requirement, g/d	
	Milking cows	1,121
	Dry cows	871
	Heifer pregnant	965
	Heifer non-pregnant	887
	Yearly heifer	648
	Calves	284
3. Buffaloes		
	Production Systems	
	Feeding Systems	Subsystem I: Natural grass and crop residues based feeding systems.
		Subsystem II: Natural grass with cut and carry and crop residues based feeding systems.
		Subsystem III: Under plantation grazing with cut and carry and crop residue feeding systems.
	Population, head	1,234,178
	Breeds	Native swamp buffalo
	Calf crop, %	35-40
	Age at first calving, year	4.5-5.5
	Callving interval, year	1.5
	Replacement rate, %	6-7
	Age at replacement, year	16-17
	Calf mortality, %	10-30
	Land use per AU, ha	.15-.20
	Animal per family, head	1-4
	Average body weight	
	Birth weight, kg	24-32
	Weaning weight, kg	90-120
	Mature cows, kg	350-440
	Mature bulls, kg	500-550
	ADG, kg	.24-.30
	Days work per year, days	60-120
	Area of land plough per year, ha	1.6

	Area of land plough per day, ha	.14-.15
	Average year of work, year	12
	Age of bullock at slaughter, year	15
	DM Requirement, kg/day	2.90-11.00
	ME Requirement, MJ/day	19.92-57.03
	DP Requirement, g/day	200-393
4. Goats and Sheep		
4.1 Dairy goats		
	Production Systems	Intensive Production Systems (IPS)
	Feeding Systems	Intensive cut and carry and crop by product systems.
	Population, head	33,363
	Breeds	Native and Native crossbred
	Number per farm, head	3-5
	Average weight, kg	30
	Milk yield, kg/day	2
	Milk fat, %	4.5
	DM Requirement, DM kg/day	1.2 (4 % BW)
	ME Requirement, MJ/day	15.6
	DP Requirement, g/day	141
4.2 Meat goat		
	Production Systems	Mixed crop-livestock systems (MCLS)
	Feeding Systems	Subsystem I: Natural grass with cut and carry and crop residues based feeding systems.
		Subsystem II: Under plantation grazing with cut and carry and crop residue feeding systems.
	Population, head	394,204
	Breeds	Native and Native crossbred
	Number per farm, head	3-5
	Average weight, kg	20
	Market age, days	180
	ADG, g	50
	DM Requirement, DM kg/day	0.60
	ME Requirement, MJ/day	5.5
	DP Requirement, g/day	32
4.3 Sheep		
	Production Systems	Mixed crop-livestock systems (MCLS)

	Feeding Systems	Subsystem I: Natural grass with cut and carry and crop residues based feeding systems.
		Subsystem II: Under plantation grazing with cut and carry and crop residue feeding systems.
	Population, head	51,735
	Breeds	Native and Native crossbred
	Number per farm, head	2-5
	Average weight, kg	30
	Market age, days	180-365
	ADG, g	50
	DM Requirement, DM kg/day	.95
	ME Requirement, MJ/day	9.58
	DP Requirement, g/day	55
5. Pigs		
5.1 Breeder pigs		
	Production Systems	Intensive Production Systems (IPS)
	Feeding Systems	Intensive compound concentrate feeding systems.
	Population, head	1,096,310
	Breeds	Exotic commercial
	Average weight, kg (sows)	150
	DM Requirement, DM g/day	5.35
	ME Requirement, MJ/day	73.12
	DP Requirement, g/day	843
5.2 Finishing pigs		
	Production Systems	Intensive Production Systems (IPS)
	Feeding Systems	Intensive compound concentrate feeding systems.
	Population, head	6,092,239
	Breeds	Exotic commercial
	Average weight, kg (sows)	20-100
	ADG, kg	0.4
	DM Requirement, DM g/day	1.5
	ME Requirement, MJ/day	20.49
	DP Requirement, g/day	203
5.3 Smallholder farms		
	Production Systems	Intensive Production Systems (IPS)

	Feeding Systems	Intensive compound concentrate feeding systems.
	Population, head	711,943
	Breeds	Exotic commercial
	Average weight, kg (sows)	20-100
	ADG, kg	.4
	DM Requirement, DM g/day	1.5
	ME Requirement, MJ/day	20.49
	DP Requirement, g/day	203
6. Poultry		
6.1 Broilers		
	Production Systems	Intensive Production Systems (IPS)
	Feeding Systems	Intensive commercial compound based feeding systems.
	Population, head	173,869,082
	Breeds	Exotic commercial
	Market weight, kg	1.5-2.0
	Market age, days	42-56
	Average Dairy Gain, g	26- 36
	Feed Conversion Ratio	2.1-2.3
	DM Requirement, g/day	70-120
	ME Requirement, MJ/day	.96
	DP Requirement, g/day	15
6.2 Layers		
	Production Systems	Intensive Production Systems (IPS)
	Feeding Systems	Intensive compound based feeding systems.
	Population, head	49,403,372
	Breeds	Exotic commercial
	Average weight, kg	1.5-2.0
	Age at first laying, days	165-180
	Average Egg Production, eggs	250-300
	Replacement age, year	1.5-2.0
	DM Requirement, g/day	110
	ME Requirement, MJ/day	1.31
	DP Requirement, g/day	17
6.3 Native chicken		
	Production Systems	Semi-intensive production Systems (SIPS)

	Feeding Systems	Semi free range and agro-by-product supplementary systems.
	Population, head	76,155,430
	Breeds	Native Thai Chicken (low growth rate, low egg production, good meat quality)
	Market weight, kg	1.5-2.5
	Market age, days	180-240
	Age at first laying, days	190-250
	Replacement age, year	3.5
	Eggs per clutch, eggs	8-16
	Average clutch per year, Clutch	3.5
	Average Dairy Gain, g	12 - 16
	DM Requirement, DM g/day	60-100
	ME Requirement, MJ/d	1.43
	DP Requirement, g/d	7
6.4 Meat ducks		
	Production Systems	Intensive Production Systems (IPS)
	Feeding Systems	Intensive commercial compound based feeding systems.
	Population, head	8,949,007
	Breeds	Exotic commercial
	Market weight, kg	2.5-3.5
	Market age, days	56-72
	Average Dairy Gain, g	15-20
	Feed Conversion Ratio	2.2-2.7
	DM Requirement, g/day	170
	ME Requirement, MJ/day	2.01
	DP Requirement, g/day	29
6.5 Layer ducks		
	Production Systems	Intensive Production Systems (IPS)
	Feeding Systems	Intensive compound based feeding systems.
	Population, head	8,174,988
	Breeds	Exotic commercial
	Average weight, kg	1.4-1.5
	Age at first laying, days	180-200
	Average Egg Production, eggs	250-300
	Replacement age, year	1.5-2

	DM Requirement, g/day	140
	ME Requirement, MJ/day	1.55
	DP Requirement, g/day	21
6.6 Smallholder ducks		
	Production Systems	Semi-intensive production Systems (SIPS)
	Feeding Systems	Semi free range and commercial compound feed supplementary systems.
	Population, head	15,055,232
	Breeds	Crossbred Native with layer or meat ducks
	Market weight, kg	1.4-1.5
	Market age, days	180-200
	Average Dairy Gain, g	250-300
	Feed Conversion Ratio	2.2-2.7
	DM Requirement, g/day	140
	ME Requirement, MJ/day	1.55
	DP Requirement, g/day	21

Annex-4: Available crop by-products as feed and composition

Feed Resources	Production (ton)	HI *	% use in feeds	Production and Composition		
				DM (%)	CP (%)	ME (MJ)
Crop and by-products						
Rice						
Rice production	39,171,852					
Rice straw		1.00	0.25	88.80	3.60	6.66
Broken rice		0.16	0.25	89.90	13.60	11.36
Rice bran		0.09	0.90	87.60	7.80	12.27
Corn						
Corn production	4,964,631					
Corn grain		1.00	0.75	87.40	8.30	14.94
Corn stem and aerial parts		2.50	0.25	21.00	8.30	9.70

Corn husk		0.10	0.25	88.50	12.00	8.94
Cassava						
Cassava production	29,410,120					
Cassava chip		0.75	0.75	89.80	2.30	15.70
Cassava residue		0.10	0.50	87.60	2.80	10.75
Cassava pulp ethanol residue		0.15	0.50	30.00	4.00	10.91
Cassava leaf		0.02	0.25	90.60	22.20	11.63
Sugar cane						
Cane production	98,400,465					
Molasses		0.05	0.50	73.70	4.50	14.94
Bagasse		0.10	0.10	91.50	3.80	8.48
Sugar cane top		0.10	0.10	28.00	7.20	8.18
Palm oil						
Palm oil seed production	11,326,660					
Palm kernel cake with coat		0.25	0.75	92.80	9.80	10.00
Palm kernel without coat		0.25	0.75	91.30	16.60	11.97
Palm fruit press		0.05	0.75	87.30	6.10	6.82
Soybean						
Soybean seed production	78,883					
Soy bean meals		0.70	0.75	90.70	45.70	13.33
Soy bean hulls		0.05	0.50	89.50	11.80	8.48
Soy bean pods		0.50	0.25	89.80	6.20	7.88
Soy bean straw		2.00	0.25	86.80	7.00	7.88
Coconuts						

Coconut production	1,036,658					
Coconut meal		0.40	0.25	92.30	17.10	15.27
Pineapple						
Pineapple production	2,450,366					
Pineapple cane residues		1.00	0.25	14.20	5.70	9.69
Pineapple crown		0.50	0.25	19.00	9.50	9.69
Pineapple aerial parts		0.50	0.10	47.80	4.60	9.69
Pineapple core		0.25	0.10	87.10	1.90	11.21
Grand Total	186,839,635					

*Harvest index = proportion of yield from crop production

Annex – 5: Estimate feed requirements (DM, ME and DP) for livestock in Thailand, 2012.

Livestock category	Number	Requirement Per Year		
		Dry matter (tons/year)	ME (million MJ)	DP (tons/year)
1. Goats and sheep				
1.1 Dairy goats	33,363	14,613	190	1,721
1.2 Meat goats	394,204	82,158	791	4,604
1.3 Sheep	51,735	17,939	181	1,039
Sub-total 1	479,302	114,710	1,162	7,364
2. Pigs				
2.1 Semi-intensive farms	711,943	350,810	4,792	52,621
2.2 Breeder farms				
2.2.1 Boars	153,724	126,246	1,725	14,203
2.2.2 Sows and piglets	942,586	1,656,571	25,155	260,910
2.3 Finishing farms				
2.3.1 Weight 20-50 kg	3,046,120	1,500,976	20,410	243,158
2.3.2 Weight 50-80 kg	2,030,746	1,601,040	21,101	223,345
2.3.3 Weight 80-200 kg	1,015,373	1,000,650	13,188	118,877
Sub-total 2	6,092,239	6,236,293	86,371	913,115
3. Dairy cattle				
3.1 Milking cows	215,868	977,019	5,043	88,326
3.2 Dry cows	70,157	368,745	1,500	22,304
3.3 Heifers pregnant	43,174	178,071	1,338	15,207
3.4 Heifer nonpregmnant	26,984	94,552	865	8,736
3.5 Yearly heifer	70,157	179,251	1,639	16,594
3.6 Calves	113,330	128,233	1,160	11,748
Sub-total 3	539,670	1,925,871	11,545	162,914
4. Buffalo				
4.1 Mature native bulls	362,373	1,454,928	7,543	51,981
4.2 Mature native cows	614,403	1,805,270	10,227	80,060
4.3 Yearly native	193,052	380,505	2,388	20,646
4.4 Calves	64,350	68,114	468	4,698
Sub-total 4	1,234,178	3,708,817	20,626	157,384
5. Cattle				
5.1 Native				
5.1.1 Native mature bulls	1,384,080	4,597,222	33,397	155,093
5.1.2 Native mature cows	1,028,541	3,115,965	22,053	152,044
5.1.3 Native yearly	1,677,776	3,429,374	26,135	184,941
5.1.4 Native calves	559,258	591,975	4,185	42,459
5.2 Crossbred				
5.2.1 Crossbred mature bulls	470,934	1,959,556	14,456	63,600

5.2.2 Crossbred mature cows	566,309	1,818,985	4,200	95,083
5.2.3 Crossbred yearly	594,656	1,541,051	12,532	91,812
5.2.4 Crossbred calves	198,218	224,284	1,813	18,956
5.3 Feedlot	103,332	346,989	3,085	33,002
Sub-total 5	6,583,104	17,625,400	121,855	836,989
6. Chicken				
6.1 Native chicken	76,155,430	1,667,804	39,775	191,797
6.2 Broilers	173,869,082	4,688,433	60,811	937,687
6.3 Broiler parent stock	14,737,437	806,875	9,621	104,894
6.4 Layers	49,403,372	1,983,545	23,653	305,466
6.5 Layer parent stock	2,371,043	103,852	1,238	12,151
Sub-total 6	316,536,364	9,250,509	135,098	1,551,994
7. Ducks				
7.1 Muscovy (meat) ducks	6,092,135	276,683	3,160	56,167
7.2 Native meat ducks	986,974	36,025	414	5,584
7.3 Meat ducks	8,949,007	559,952	6,560	95,192
7.4 Native layer ducks	7,976,123	393,023	4,522	60,919
7.5 Layer ducks	8,174,988	402,823	4,635	62,437
Sub-total 7	32,179,227	1,668,506	19,292	280,298
Grand Total		**40,530,105**	**395,950**	**3,910,058**

Annex-6: Daily feed (DM, ME, DP) requirements of livestock in Thailand

Livestock category	Daily Requirements		
	Dry matter (kg/day)	ME (MJ/day	DP (g/day)
1. Goats and sheep			
1.1 Dairy goats	1.20	15.60	141
1.2 Meat goats	0.57	5.50	32
1.3 Sheep	0.95	9.58	55
2. Pigs			
2.1 Semi-intensive farms	1.35	18.44	203
2.2 Breeder farms			
2.2.1 Boars	2.25	30.74	253
2.2.2 Sows and piglets	4.82	73.12	758
2.3 Finishing farms			
2.3.1 Weight 20-50 kg	1.35	18.36	219
2.3.2 Weight 50-80 kg	2.16	28.47	301
2.3.3 Weight 80-200 kg	2.70	35.58	321
3. Dairy cattle			
3.1 Milking cows	12.40	64.00	1,121
3.2 Dry cows	14.40	58.58	871
3.3 Heifers pregnant	11.30	84.94	965

3.4 Heifer non-pregnant	9.60	87.86	887
3.5 Yearly heifer	7.00	64.02	648
3.6 Calves	3.10	28.03	284
4. Buffalo			
4.1 Mature native bulls	11.00	57.03	393
4.2 Mature native cows	8.05	45.61	357
4.3 Yearly native	5.40	33.89	293
4.4 Claves	2.90	19.92	200
5. Cattle			
5.1 Crossbred mature bulls	11.40	84.10	370
5.2 Crossbred mature cows	8.80	20.32	460
5.3 Crossbred yearly	7.10	57.74	423
5.4 Crossbred calves	3.10	25.06	262
5.5 Feedlot	9.20	81.79	875
6. Chicken			
6.1 Native chicken	0.06	1.43	7
6.2 Broilers	0.07	0.96	15
6.3 Broiler parent stock	0.15	1.79	20
6.4 Layers	0.11	1.31	17
6.5 Layer parent stock	0.12	1.43	14
7. Ducks			
7.1 Muscovy (meat) ducks	0.12	1.42	25
7.2 Native meat ducks	0.10	1.15	16
7.3 Meat ducks	0.17	2.01	29
7.4 Native layer ducks	0.14	1.55	21
7.5 Layer ducks	0.14	1.55	21

Annex-7 Rice (Major and second rice): Area, production, yield per rai, farm price and farm value in Thailand

Year	Planted area[1] (1,000 rais)	Harvested area (1,000 rais)	Production (1,000 tons)	Yield per rai (kgs.)	Farm price[2] (Baht per ton)	Farm value (Million baht)
2002	66,440	60,335	27,992	464	5,051	141,387
2003	66,404	63,524	29,474	464	5,569	164,138
2004	66,566	62,456	28,874	462	6,922	199,866
2005	67,677	63,906	30,648	480	6,832	209,387
2006	67,616	63,532	29,990	472	11,271	338,017
2007	70,187	66,681	32,477	487	9,689	314,670
2008	69,824	66,772	32,023	480	9,973	319,365
2009	72,720	69,627	32,398	465	10,810	350,222

2010	80,676	75,747	35,703	471	11,841	422,759
2011	83,405	74,729	38,102	510	11,358	432,763
2012	81,038	74,729	38,000	509	11,426	434,191
2013	80,845	76,648	38,247	499	8,441	322,840
%change, 2009-3013	11.17	10.08	18.05	7.31	-21.91	-7.82

[1]1 rai = 0.16 hectare or 0.395 acre, [2]1 Baht = 0.3107 US dollar

Source: OAE (2014)

Annex-8 Maize/corn: Area, production, yield per rai, farm price and farm value in Thailand

Year	Planted area[1] (1,000 rais)	Harvested area (1,000 rais)	Production (1,000 tons)	Yield per rai (kgs.)	Farm price[2] (Baht per kg.)	Farm value (Million baht)
2002	7,374	7,167	4,259	594	4.14	17,633
2003	7,067	6,895	4,249	616	4.43	18,823
2004	7,272	7,032	4,341	617	4.59	19,927
2005	6,906	6,704	4,094	611	4.78	19,569
2006	6,405	6,223	3,918	630	5.45	21,355
2007	6,364	6,187	3,890	629	6.89	26,804
2008	6,692	6,518	4,249	652	7.01	29,788
2009	7,099	6,905	4,616	668	5.43	25,065
2010	7,481	7,268	4,861	669	8.13	39,518
2011	7,401	7,179	4,973	693	7.63	37,944
2012	7,529	7,154	4,948	692	9.34	46,210
2013	7,541	7,162	5,063	707	7.00	35,440
%change, 2009-2013	6.23	3.72	9.68	5.84	28.91	41.39

[1]1 rai = 0.16 hectare or 0.395 acre, [2]1 Baht = 0.3107 US dollar

Source: OAE (2014)

Annex-9 Cassava: Area, production, yield per rai, farm price and farm value in Thailand

Year	Planted area[1] (1,000 rais)	Harvested area (1,000 rais)	Production (1,000 tons)	Yield per rai (kgs.)	Farm price[2] (Baht per kg.)	Farm value (Million baht)
2002	6,224	6,176	16,868	2,731	1.05	17,712

2003	6,435	6,386	19,718	3,087	0.93	18,337
2004	6,524	6,162	16,938	2,749	1.33	22,528
2005	6,933	6,693	22,584	3,375	1.29	29,134
2006	7,623	7,339	26,916	3,668	1.18	31,760
2007	7,750	7,397	25,156	3,401	1.93	48,551
2008	8,584	8,292	30,088	3,628	1.19	35,805
2009	7,669	7,405	22,006	2,972	1.84	40,491
2010	7,400	7,096	21,912	3,088	2.68	58,725
2011	9,242	8,513	29,848	3,506	2.09	62,382
2012	9,037	8,657	30,228	3,492	2.12	64,082
2013	8,666	8,316	29,199	3,511	2.15	62,779
%change, 2009-2013	13.00	12.30	32.69	18.14	16.85	55.04

[1]1 rai = 0.16 hectare or 0.395 acre, [2]1 Baht = 0.3107 US dollar
Source: OAE (2014)

Annex-10 Sugarcane: Harvested area, production, yield per rai, farm price and farm value in Thailand

Year	Harvested area[1] (1,000 rais)	Production (1,000 tons)	Yield per rai (kgs.)	Farm price[2] (Baht per ton)	Farm value (Million baht)
2002	6,320	60,013	9,496	435	26,106
2003	7,121	74,259	10,429	469	34,827
2004	6,670	49,586	7,434	520	25,785
2005	6,033	47,658	7,899	688	32,789
2006	6,314	64,365	10,194	683	43,962
2007	6,588	73,502	11,157	577	42,410
2008	6,023	66,816	11,094	700	46,772
2009	6,310	68,808	10,905	861	59,244
2010	7,870	95,950	12,192	908	87,123
2011	8,013	98,400	12,280	954	93,874
2012	8,260	100,096	12,118	917	91,788
2013	8,373	102,979	12,299	853	87,814
%change, 2009-2013	32.69	49.66	12.78	-0.93	48.22

[1]1 rai = 0.16 hectare or 0.395 acre, [2]1 Baht = 0.3107 US dollar
Source: OAE (2014)

Annex-11 Oil palm: Area, production, yield per rai, farm price and farm value in Thailand

Year	Planted area[1] (1,000 rais)	Harvested area (1,000 rais)	Production (1,000 tons)	Yield per rai (kgs.)	Farm price[2] (Baht per kg.)	Farm value (Million baht)
2002	1,956	1,644	4,001	2,434	2.30	9,203
2003	2,057	1,799	4,903	2,725	2.34	11,472
2004	2,405	1,932	5,182	2,682	3.11	16,115
2005	2,748	2,026	5,003	2,469	2.76	13,807
2006	2,957	2,374	6,715	2,828	2.39	16,049
2007	3,200	2,663	6,390	2,399	4.07	26,007
2008	3,676	2,885	9,271	3,214	4.23	39,214
2009	3,890	3,188	8,163	2,561	3.64	29,712
2010	4,077	3,552	8,223	2,315	4.26	35,031
2011	4,098	3,565	10,760	3,018	5.34	57,458
2012	4,405	3,714	11,358	3,058	4.91	55,768
2013	4,504	3,915	12,812	3,273	3.54	45,354
%change, 2009-2013	15.78	22.80	56.95	27.80	-2.75	52.65

[1]1 rai = 0.16 hectare or 0.395 acre, [2]1 Baht = 0.3107 US dollar

Source: OAE (2014)

Annex-12 Soybeans: Area, production, yield per rai, farm price and farm value in Thailand

Year	Planted area[1] (1,000 rais)	Harvested area (1,000 rais)	Production (1,000 tons)	Yield per rai (kgs.)	Farm price[2] (Baht per kg.)	Farm value (Million baht)
2002	1,093	1,093	260	238	10.40	2,703
2003	936	936	231	246	10.79	2,487
2004	945	912	218	238	10.88	2,367
2005	929	901	226	250	10.15	2,291
2006	886	860	215	250	10.72	2,302
2007	816	790	201	255	15.12	3,044
2008	753	729	187	256	15.46	2,885
2009	688	667	176	264	13.87	2,443
2010	577	561	152	271	15.36	2,335

2011	377	365	96	263	14.87	1,430
2012	316	311	85	272	18.39	1,557
2013	259	255	70	276	17.96	1,265
%change, 2009-2013	-62.31	-61.72	-60.00	4.55	29.49	-48.22

[1]1 rai = 0.16 hectare or 0.395 acre, [2]1 Baht = 0.3107 US dollar
Source: OAE (2014)

Annex-13 Coconuts: Area, production, yield per rai, farm price and farm value in Thailand

Year	Planted area[1] (1,000 rais)	Harvested area (1,000 rais)	Production (1,000 tons)	Yield per rai (kgs.)	Farm price[2] (Baht per ton)	Farm value (Million baht)
2002	1,887	1,833	2,037	1,111	2,608	5,313
2003	1,782	1,740	2,117	1,217	2,688	5,691
2004	1,727	1,693	2,130	1,258	3,456	7,361
2005	1,690	1,662	1,874	1,128	3,512	6,581
2006	1,635	1,617	1,818	1,125	4,632	8,421
2007	1,614	1,601	1,724	1,077	3,312	5,710
2008	1,546	1,539	1,486	966	4,792	7,121
2009	1,496	1,490	1,383	928	4,624	6,395
2010	1,453	1,446	1,249	863	5,104	6,375
2011	1,357	1,350	1,055	782	10,608	11,195
2012	1,337	1,332	1,057	793	4,760	5,030
2013	1,308	1,304	1,010	775	6,712	6,779
%change, 2009-2013	-12.57	-12.48	-26.97	-16.49	45.16	6.00

[1]1 rai = 0.16 hectare or 0.395 acre, [2]1 Baht = 0.3107 US dollar
Source: OAE (2014)

Annex-14 Para rubber: Area, production, yield per rai, farm price and farm value in Thailand

Year	Planted area[1] (1,000 rais)	Harvested area (1,000 rais)	Production (1,000	Yield per rai (kgs.)	Farm price[2] (Baht per	Farm value (Million

			tons)		kg.)	baht)
2004	12,954	10,350	3,007	291	44.13	132,699
2005	13,609	10,569	2,980	282	53.57	159,639
2006	14,355	10,893	3,071	282	66.24	203,423
2007	15,362	11,043	3,022	274	68.9	208,216
2008	16,717	11,372	3,167	278	73.66	233,281
2009	17,254	11,600	3,090	266	58.47	180,689
2010	18,095	12,058	3,052	253	103.00	314,333
2011	18,461	12,766	3,349	262	124.00	415,263
2012	21,958	13,807	3,625	262	87.15	315,944
2013	22,177	15,130	3,863	255	74.75	288,759
%change, 2009-2013	28.53	30.43	25.02	-4.14	27.84	59.81

[1]1 rai = 0.16 hectare or 0.395 acre, [2]1 Baht = 0.3107 US dollar

Source: OAE (2014)

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