Sustainable livestock production models: Intensive silvopastoral systems – ISS – in Latin America

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Few animal species were domesticated before the European invasion of the Americas: the Andean camelids (alpaca, llama), guinea pig, musk duck and turkey.

Guinea pig o cuia *Cavia porcellus* L.
8000 years of domestication in the Andes.

Llama *Lama glama* L.
Artiodactyl of the Camelidae family;
6000 to 8000 years of domestication in Upper Peru

Turkey o Guajolote *Meleagris gallipavo* L.,
8000 years of domestication in Mexico
Animals brought by the Spanish and Portuguese conquerors forever transformed the Americas.

Bennet & Hoffman, 1992

San Alfonso San Miguel-Ayanz 2002
Pastures in South America

550 million hectares in Latin America (2007)
27% of area
38 million hectares in Colombia

Soil losses of 30-40 ton ha\(^{-1}\) yr\(^{-1}\) are common throughout Latin America.

FAO, 2010
The Climate Change in Latin America
Mexico: Atypical drought and frost 2012

Argentina: Strong frost 2013
2014 drought in Colombia

Losses for the Livestock Sector

- Weight loss of animals: US$ 2.65 millions
- Decreased milk production: US$ 19 millions
- Loss of fertility in cows: US$ 59.5 millions
- Soil and pasture degradation: US$ 32 millions
Environmental transformation of livestock production: a priority for Latin America

Cattle production needs to shift from its current path of degradation of the natural and social capitals, onto one which generates goods (milk, meat, and timber) while maintaining some ecosystem attributes and services.
This change should incorporate 5 agroecological principles:

1. Increasing plant biomass (trees, shrubs and pasture)
2. Curbing soil degradation and promoting its recovery
3. Protecting water sources and using them rationally
4. Increasing animal productivity on a per hectare basis.
5. Conserving biodiversity
Intensive silvopastoral system ISPS

An agroforestry system that can be directly grazed by livestock. It combines:

- Fodder shrubs planted at high densities (>10,000 plants ha⁻¹), intercropped with
- Highly-productive pastures
- 500 timber trees planted in east-west lines to minimize shading.

Murgueitio et al., 2011
What is *intensive* about ISPS?

**Efficiency of agroecological processes:**

- Photosynthesis & biomass production
- Nitrogen fixation
- Solubilization of soil phosphorus and other nutrients
- Organic matter and soil biological activity
- Efficient use of water

The “inputs” of the system are the natural processes themselves.

The Guabo Farm Edilberto Serracín, Chiriquí Panamá. Fernando Uribe CIPAV
The key to successful ISS is the adequate selection of the species, particularly the fodder shrub that is the backbone of the system.

Two species have shown the best results:

Mexican sunflower *Tithonia diversifolia* Helm, Asteraceae

Leucaena *Leucaena leucocephala* (Lam.) de Wit, Fabaceae
Two other species of fodder shrubs have shown promising results.

**Sauco Sambucus nigra L. (S. peruviana Kunth), Family: Adoxaceae**

**Guacimo Guazuma ulmifolia L., Family: Malvaceae**
**Intensive Silvopastoral Systems iSPS**

Pasture, timber trees, fruit trees or palms (25 to 200 mature trees per hectare) for direct grazing of livestock.

*With permanent supply of mineralized salt and good quality water in mobile troughs.*

Chandio *ejido*, Michoacan, Mexico. Red mexicana SSPI 2013
Intensive Silvopastoral Systems iSPS
Live fences are planted at the periphery and internal divisions of pastures.
Cattle are handled without violence with fixed or movable fences or electrical tape.

La Esperanza farm, Pereira Colombia
Ganaderia Colombiana Sostenible project
Fernando Uribe CIPAV 2014
Fattening of steers in iSPS
Dry Caribbean region, Cesar (Colombia)

1800 Kg ha\(^{-1}\) yr\(^{-1}\)

La Luisa, Dry Caribbean region of Colombia.
Fernando Uribe, 2014.
Water is always priority 1.
Milk quality depends on water quality
Water goes to the livestock.
Animals never again fetch water.

Rincón de Luna farm (Estancia), Corrientes (Argentina), October 2013
Water goes to the livestock; animals never again fetch water.

Otto Waidelich, Misiones, Argentina 2012
Where is the water for livestock?

Gray water

Blue Water

Green Water
>90% in Latin American cattle ranching

Atlántico, dry Caribbean region (Colombia); March 2013
Nearly all cattle ranching in Latin America depends on the Green Water cycle.
How can we improve the use of green water in rainfed livestock production?

1. Reducing water loss through runoff.
2. Harvesting and storing rainwater at all scales.
3. Improving infiltration of rain water into the soil.
4. Cutting down evaporation and evapotranspiration.
5. Accumulating water within soil organic matter.
6. Accumulating water in plant biomass.
Harvesting and storing water

Harvesting rainwater from ceilings to supply farm aqueducts
Rainwater harvest, Casanare farm, San Diego, Cesar 2014 Corpoica- CIPAV agreement.
Water harvest below a reforested hill. La Unión, Valle del Cauca (Colombia) Surrounding vegetation reduces evaporation from the pond.

Enrique Murgueitio CIPAV 2010
Intensive Silvopastoral System - ISPS
The Six Green Water strategies together in a single rainfed livestock land use.

Rancho Las Tinajas, Michoacan, Mexico 2013.
Fernando Uribe, CIPAV
### iSPS Productivity in the Caribbean region of Colombia

#### Productive parameters and stocking rates for different scenarios

<table>
<thead>
<tr>
<th>System</th>
<th>DP</th>
<th>IP</th>
<th>iSPS</th>
<th>iSPS + Timber</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant productivity; t DM/ha/yr</td>
<td>7</td>
<td>19.2</td>
<td>28</td>
<td>28</td>
</tr>
<tr>
<td>Stocking rate AU/ha (1 AU=450 kg)</td>
<td>0.85</td>
<td>2.34</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Yield; kg beef/ha/yr</td>
<td>77.6</td>
<td>341.6</td>
<td>711.8</td>
<td>711.8</td>
</tr>
</tbody>
</table>

DP Degraded pasture  
IP Improved pasture  
iSPS Intensive Silvopastoral System  
iSPS Intensive Silvopastoral System with timber trees

Naranjo et al., 2012
iSPS in tropical Pacific region of Mexico
4 AU ha\(^{-1}\); daily weight gain (800 a 1000 g animal\(^{-1}\) day\(^{-1}\))
Solorio et al 2011, México
Intensive Silvopastoral Systems: key habitats for dung beetle conservation in livestock farms of the Cesar river valley (Colombia)

Giraldo, C., Montoya, S., Montoya, J., Chará, J. & Escobar., F. 2014
Evaluated land uses

Tropical Dry Forest

iSPS

Improved pasture

Giraldo, C., Montoya, S., Montoya, J., Chará, J. & Escobar, F. 2014
Dung beetle abundance

Giraldo, C., Montoya, S., Montoya, J., Chará, J. & Escobar, F. 2014
<table>
<thead>
<tr>
<th></th>
<th>Tropical dry forest</th>
<th>iPSS</th>
<th>Improved pasture</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tunnel depth</strong>&lt;br&gt;(average in cm)</td>
<td>16.5</td>
<td>23</td>
<td>8.4</td>
</tr>
<tr>
<td><strong>Number of nesting balls</strong>&lt;br&gt;Ha^{-1}</td>
<td>6.600</td>
<td>5.160</td>
<td>3.920</td>
</tr>
<tr>
<td><strong>Soil removed</strong>&lt;br&gt;(Kg Ha^{-1})</td>
<td>854.0</td>
<td>470.9</td>
<td>46.7</td>
</tr>
<tr>
<td>~1 Ton Ha^{-1}</td>
<td>~0.5 Ton Ha^{-1}</td>
<td>~0.05 Ton Ha^{-1}</td>
<td></td>
</tr>
</tbody>
</table>
Different situations drive the convergence towards iSPS in Latin America

1. Lands degraded by grazing or rainfed agriculture.
2. Intensive livestock grazing systems relying on high inputs.
3. Timber plantations.
4. Fruit and nut tree plantations.
5. Regions affected by frost and unsustainable situations.
From lands degraded by grazing or rainfed agriculture to iSPS

Strategy
Increasing stocking rates and animal productivity and reducing the seasonality of production during the dry periods

Farming system
Breeding, dual-purpose (meat and milk), fattening, buffalo, sheep

Outcome
More milk and meat: 300 to 500% per hectare

Countries
Brazil, Colombia, Cuba, Mexico, Nicaragua, Panama, Paraguay, Venezuela
Maranhão, Brasil
Fazenda Monaliza

Soccer court type grazing in the Amazon

1 AU ha\(^{-1}\)
500 g animal\(^{-1}\) day\(^{-1}\)

4 AU ha\(^{-1}\)
700 g animal\(^{-1}\) day\(^{-1}\)

Mauroni Cangassu 2013
From intensive livestock grazing systems that depend on high inputs to iSPS

Strategy
Reducing the costs of fertilizers and commercial feeds.

Farming system
Dairy, dual-purpose (meat and milk) and fattening.

Outcome
Cheaper milk and meat 35% to 45% less L⁻¹.

Countries
Colombia and Mexico
2006: 60 animals. Milk production cost: US $ 0.45 L$^{-1}$
2012: 250 animals. Milk production cost : US $ 0.25 L$^{-1}$
La Sofía and La Joya farms
Valle del Cauca, Colombia
Eduardo and Álvaro Llano, 2014
Tithonia diversifolia and stargrass ISPS for hair sheep
40 - 50 animals per hectare

Tinajas farm, Caldas (Colombia)
Strategy
Generating cash flow (short-term income) until the timber harvest and products with a higher market value than cellulose (larger diameter boles)

Production system
Breeding heifers; fattening

Outcome
Small and medium producers entering the forestry business.

Countries
Argentina, Brazil, Colombia, Chile, Uruguay, Venezuela
From pastures to timber plantations and then to ISPS
Northwestern Argentina (Misiones and Corrientes)

Cow mortality caused by frost in Corrientes, 2013

Esquivel and colleagues, 2013
Homogeneous plantation or SPS: change in diameter (cm)

Lacorte and Esquivel 2011
Net change in per hectare income during 18 years

1996

Forestry

SPS

Ranching

AÑO 1996

FORESTAL

SSP

GANADERIA

AÑO 2013

FORESTAL

SSP

GANADERIA

Esquivel and colleagues 2013
Conceptual scheme for the different products (tonnes ha$^{-1}$)
Forestry vs Silvopastoral system (SPS) in Misiones and Corrientes (Argentina)

- Cellulose: 20 t and 10 t
- Sawmilling: 240 t and 120 t
- Laminating: 40 t and 80 t

$\text{Esquivel and colleagues, CREA 2014}$

$\text{increment}$
## Financial indicators - fattening of cattle in the dry Caribbean region of Colombia

Pasture rotation without external fertilization and irrigation vs. SSPI with and without forest products

**US $**  
**Annual interest rate: 10%**

<table>
<thead>
<tr>
<th>System</th>
<th>Gross income ha(^{-1}) yr(^{-1})</th>
<th>Profitableness ha(^{-1}) yr(^{-1})</th>
<th>Internal rate of return</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pasture with no fertilization and irrigation</td>
<td>514</td>
<td>(-193.86)</td>
<td>Non-viable</td>
</tr>
<tr>
<td>iSPS with timber trees</td>
<td>3839</td>
<td>1623</td>
<td>37.0 %</td>
</tr>
<tr>
<td>iSPS without timber trees</td>
<td>2935</td>
<td>954</td>
<td>32.7 %</td>
</tr>
</tbody>
</table>

Murgueitio et al. 2014
The future of precious woods is in pastoral areas.

Mahogany *Swietenia macrophylla* King
From fruit and nut tree plantations to iSPS

Strategy
Using non-productive areas within the main crop and reducing costs (weed control, fertilizer)

Farming system
Breeding heifers, fattening, dual purpose, sheep

Outcome
20 – 30% cost reduction, enhanced cash flow during the first 4 years
Diversification of income

Countries
Brasil, Colombia, Mexico
80 years of lemon monoculture begin to change: lemon with iSPS

Intensive silvopastoral system integrated into a lemon orchard. La Concha ejido, Apatzingan, Michoacan, Mexico.

Ranferi Maldonado, U Chapingo – FPM 2013
“Shade lemon”:
• More abundant, larger, juicier and organic lemons.
• Access to a specialized market, with premium price.

Lower production cost:
Pest control (30%, decreases to 0%)
Weed control (30%, decreases to 0%)
Pruning (20%, increases to 30%)

Calle and colleagues 2013
Ranferi Maldonado, U Chapingo – FPM 2013
Caryodendron orinocense H. Karst. Euphorbiaceae

The Colombian nut: inchi or cacay
iSPS in regions affected by frosts

Strategy
Urgent adaptation to climate change; cutting down the effects of frost and pests

Production system
Dairy, sheep, breeding heifers

Outcome
80% reduction in frost damage to fodder; reduction of pesticide application on pasture (>10 yr⁻¹ to zero)

Countries
Argentina, Brazil, Colombia, Uruguay
Sabana de Bogotá, Colombia.
Frost during 2009-2010 El Niño

Sopó, Cundinamarca, Colombia
Day temperature: 24°C, night temperature -5°C
Aliso Alnus acuminata and Sambucus nigra (S. peruviana)

Belén, Boyacá
Colombia
Manuel Fajardo Fabegan 2012
Herbivory on *Pennisetum clandestinum* Hochst. ex Chiov. in Colombia

*Collaria scenica*  Miridae

Hemiptera

**ISPS:** *Alnus acuminata* + *Tithonia diversifolia* + *Pennisetum clandestinum*

Grass monoculture: 10 – 14 pesticide applications per year

Zero pesticide applications

Lopera y col 2014
Tepeque cheese
(intensive silvopastoral Cotija type cheese)
Los Huarinches, Mexico

National exhibitions of cheese EXPOQUESOS and milk products EXPOLACTEA 2013

Pleasant aroma, well developed. Pronounced flavor, deeply salty, distinctively yeasty. In the end, leucaena flavor!
Valle del Cauca, Colombia

*Labrantio* artisanal, mature, Paipa type cheese. La Joya and La Sofía dairies. Eduardo and Tomás Llano 2014
Breaking the paradigm of meat quality in tropical grasslands: fattenning in iSPS
Gabriela Corral Flores PhD
Intramuscular fat and fatty acid profile of beef steers fed in three feeding systems (P <0.05) (Longissimus dorsi between 12 and 13 intercostal space)

<table>
<thead>
<tr>
<th>Test</th>
<th>Commercial feed</th>
<th>ISPS + rice flour</th>
<th>ISPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>IMF Intramuscular fat</td>
<td>5.47 ± 0.36&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.94 ± 0.39&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.79 ± 0.34&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>SFA Saturated fatty acids</td>
<td>56.92 ± 2.71&lt;sup&gt;a&lt;/sup&gt;</td>
<td>54.49 ± 2.12&lt;sup&gt;a&lt;/sup&gt;</td>
<td>50.59 ± 2.12&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>USFA Unsaturated Fatty Acids</td>
<td>33.80 ± 2.41&lt;sup&gt;b&lt;/sup&gt;</td>
<td>31.56 ± 1.89&lt;sup&gt;b,c&lt;/sup&gt;</td>
<td>40.46 ± 1.89&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>PUSFA Polyunsaturated fatty acids</td>
<td>9.28 ± 2.27&lt;sup&gt;b&lt;/sup&gt;</td>
<td>13.98 ± 1.77&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8.95 ± 1.77&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Ω - 6</td>
<td>8.82 ± 2.11&lt;sup&gt;b&lt;/sup&gt;</td>
<td>11.88 ± 1.65&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.35 ± 1.65&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Ω - 3</td>
<td>ND</td>
<td>1.47 ± 0.84&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.08 ± 0.84&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>
Carajá monkey *Alouatta caraya* eating leucaena in 12 year old trees. 
*Rincón de Luna* farm (Estancia), Corrientes, Argentina

*Forpus conspicillatus* eating seeds of *Tithonia diversifolia* 
*Finca La Cabaña*, Alcalá. Valle del Cauca. Colombia 
Alirio Bolívar, August 20, 2014

iSPS support biodiversity
Planting trees gives us a sense of belonging to the land and a reason to stay

Luis Alfredo Quenza
El Paraiso farm, Arauca. Colombia
Planting trees gives us a sense of belonging to the land and a reason to stay
Diana Pizano
El Cubo farm, Sopó Colombia

Natalia Gómez
April 12, 2014