Impact from the Adoption of improved Forages in Smallholder farms in Central America

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Content

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Federico Holmann[1], Pedro Argel[2], and Edwin Perez[3]

Introduction

Beef production in Central American countries has been characterized by large fluctuations that depend on climatic conditions, the introduction of improved forage cultivars, market prices, and international free trade agreements. In the 1970s, intensive milk and beef production systems were based on the use of star grass (*Cynodon* sp.), which predominated in the main livestock areas of the region. The degradation of this grass because of the lack of proper management practices and the absence of new options as a result of limited forage research caused a dramatic decrease in the livestock herd in the early 1980s.

In late 1975, the Tropical Forages Program of the International Center for Tropical Agriculture (CIAT) launched the International Network for Evaluation of Tropical Pastures (RIEPT, its Spanish acronym) with funding from international institutions and support of the national research programs. The network mainly aimed to evaluate new improved forage species that were adapted to the lowlands of tropical America. The RIEPT began operations in Central America in 1985 and, after 11 years of research, identified in 1996 several good-quality grass and legume accessions adapted to different agro-ecological areas. These materials were subsequently released as commercial cultivars by national agricultural research institutes (Holmann et al., 2005). Among these are the grass cultivars Diamantes (*Brachiaria brizantha* CIAT 6780) and Toledo (*B. brizantha* CIAT 26110) and the *Brachiaria* hybrid cv. Mulato in Costa Rica, as well as the legumes *Arachis pintoi* cv. Porvenir in Costa Rica and cv. Pico Bonito in Honduras, and *Cratylia argentea* cv. Veraniega in Costa Rica. These materials are now widely used in the different livestock areas of Central America. Table 1 lists the grass and legume species that have been released in the region since 1983.

Table 1. Grasses and legumes released as new cultivars in Mexico, Central America, and Panama between 1983 and 2005.

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Species	Accession (CIAT No.)	Cultivar (cv.)	Year of release	Country
Grasses				
Andropogon gayanus	621	Veranero	1983	Panama
		Llanero	1986	Mexico
		Otoreño 1	1989	Honduras
		Veranero	1989	Costa Rica
		Gamba	1989	Nicaragua
		ICTA-Royal	1992	Guatemala
Brachiaria humidicola	6133	Guanaca	1992	Panama
(formerly *B. dictyoneura)*		Brunca	1994	Costa Rica
Brachiaria humidicola	679	Humidicola	1991	Mexico
		Humidicola	1990	Panama
Brachiaria brizantha	6780	Insurgente	1989	Mexico
	6780	Diamantes 1	1991	Costa Rica
	26110	Toledo	2000	Costa Rica
Brachiaria decumbens	606	Señal	1989	Panama
	606	Pasto peludo	1991	Costa Rica
Brachiaria hybrid	36061	Mulato	2000	Mexico
Legumes				
Arachis pintoi	17434	Pico bonito	1993	Honduras
	17434	Maní Mejorador	1994	Costa Rica
	18744	Porvenir	1998	Costa Rica
Arachis sp.	18744A	Falconiana	2004	Costa Rica
Clitoria ternatea	20692	Clitoria	1990	Honduras
Centrosema pubescens	438	El Porvenir	1990	Honduras
Cratylia argentea	18516/18668	Veraniega	2001	Costa Rica
Clitoria ternatea	20692	Tehuana	1988	Mexico
		Clitoria	1990	Honduras
Pueraria phaseoloides	9900	Jarocha	1989	Mexico

Source: Adapted from CIAT (2004).

Of all the cultivars that have been released, *Brachiaria* grasses currently dominate the market, accounting for 84% of all seed sales in Mexico and Honduras, 90% in Nicaragua, 85% in Costa Rica, and 97% in Panama during the first years of the new millennium (Holmann et al., 2004).

Objective

This study aims to estimate the benefits received by 56 producers who adopted improved forages as part of a project[4] carried out in Guatemala, Honduras, Nicaragua, and Costa Rica in terms of increased productivity, stocking rate, and income due to the additional sale of milk and beef in retribution for family labor.

Materials and Methods

Data used to estimate the benefits received from the adoption of improved forages were obtained from a survey carried out between September and October 2007 that included nine producers in Guatemala, 16 in Honduras, 16 in Nicaragua, and 15 in Costa Rica who had adopted different grass and legume options during the period 2003-2007.

The survey aimed to quantify the changes observed between 2003 and 2007 in terms of land use as a result of the adoption of improved forages, changes in animal inventory by category, milk and beef production, use of family and hired labor, and expenses incurred in animal supplementation during the dry season.

Results and Discussion

Area planted with improved pastures

Tables 2 and 3 present the area planted to improved forages on surveyed farms in each of the four countries participating in the project as well as the amount of seed of each cultivar purchased for the respective plantings.

Table 4 indicates the changes in land use on the farms participating in the project as a result of the adoption of improved forages. The area planted to improved pastures increased in all countries, ranging from 12% in Guatemala to 105% in Nicaragua. The low percentage of adoption in Guatemala was mainly due to two factors: (a) Hurricane Stan that hit Guatemala in late 2005, destroying most of the plantings of improved pastures that had been carried out in 2004 and 2005; and (b) the area under improved pastures in surveyed farms was already very high at the onset of the project, thanks to past technology transfer efforts made by the national institution, ICTA. (Instituto de Ciencia y Tecnología Agropecuaria).

Table 2. Country, region, number of farms, and area established with improved grasses.

Country	Region	Farms (no.)	Planted area (estimated in ha)

[4] CFC/FIGMDP/10 "*Mejorando la Productividad, Calidad, Inocuidad y Comercio de Carne Vacuna en Centro América*", 2003-2007.

Guatemala	Cuyuta		11.3
	Nueva Concepción	3	9.7
	Coatepeque	3	11.2
	Subtotal	**12**	**32**
Honduras	Olancho	10	18.0
	Olanchito	5	10.1
	Yoro	5	12.4
	Subtotal	**20**	**40.8**
Nicaragua	Boaco	10	35.2
	Chontales	7	29.0
	Subtotal	**17**	**64.2**
Costa Rica	Pérez Zeledón	11	10.3
	Guanacaste-Nicoya	15	40.0
	Subtotal	**22**	**50.3**
Total		**56**	**187.5**

Table 3. Amount of seed (kg) of improved grasses distributed to Central American countries from 2003 to 2007.

Species/Cultivar	**Country**				**Total**
	Guatemala	**Honduras**	**Nicaragua**	**Costa Rica**	
Brachiaria hybrid cv. Mulato	86	133	36	129	384
B. brizantha cv. Toledo	24	55	69		148
B. brizantha cv. Marandu	14		83	36	133
B. decumbens cv. Basilisk	14		76	70	160
Panicum maximum cv. Tanzania		45		20	65
Paspalum atratum cv. Pojuca			47	15	62
Cratylia argentea cv. Veraniega	15	54	39	45	153
Arachis pintoi cv. Porvenir	99	118	18	135	370
Stylosanthes guianensis CIAT 3308	1				1
Pueraria phaseoloides cv. Kudzú				20	20
Leucaena leucocephala CIAT 17263			5		5
Total	**253**	**405**	**373**	**470**	**1,501**

Table 4. Changes in land use in terms of planting of improved grasses and number of existing paddocks.

Parameter	Country							
	Guatemala (n=9)		Honduras (n=16)		Nicaragua (n=16)		Costa Rica (n=15)	
	2003	**2007**	**2003**	**2007**	**2003**	**2007**	**2003**	**2007**
Total farm area	37.5	33.3	57.4	59.9	61.2	69.3	46.1	46.1
Area planted to crops	3.4	3.0	1.4	2.9	2.5	2.4	0.1	0.6
Area in stubble/forest	0.6	0.5	3.6	0.2	9.4	9.8	5.3	4.8
Area planted to grasses	33.2	29.2	52.5	57.5	49.3	57.1	36.8	43.0
Brachiaria hybrid Mulato	0.0	3.3	0.0	6.4	0.0	0.5	0.0	5.0
Brachiaria brizantha cv. Toledo	0.0	0.6	0.5	4.4	0.1	2.5	1.4	3.2
Brachiaria brizantha cv. Marandú	1.9	3.6	0.3	3.6	0.4	1.5	4.2	10.6
Brachiaria decumbens	3.6	3.6	6.6	8.2	0.2	0.5	1.5	2.0
Brachiaria humidicola	0.0	0.0	9.4	13.3	0.0	0.0	0.0	0.2
Cynodon dactilon	5.6	2.7	12.8	6.9	0.0	0.0	0.4	0.3
Panicum maximun	4.2	3.9	6.6	1.2	0.0	0.0	2.2	2.5
Hyparrhemia rufa	0.0	0.1	11.4	6.3	25.0	11.0	11.4	4.2
Alemán	0.2	0.2	0.6	0.6	0.0	0.0	0.0	0.0
Angleton	2.4	1.4	0.0	0.0	1.2	1.2	4.6	3.6
Cut-and-carry grass (King grass)	2.1	1.9	0.3	0.3	0.3	0.7	0.1	0.2
Cratylia argentea	0.0	0.3	0.0	0.3	0.1	0.3	0.0	0.3
Grass/legume associations	0.0	0.9	0.0	0.8	0.0	0.2	0.0	0.3
Native	13.0	6.5	1.4	0.3	20.3	37.8	10.5	9.8
Others	0.3	0.3	3.1	5.5	1.6	1.0	0.4	0.9
Total area under improved pastures	20.2	22.7	39.7	50.8	4.0	8.3	14.9	29.0
Increase in area under improved pastures between 2003 and 2007 (%)	NA	12.2	NA	28.0	NA	105.0	NA	96.0
Number of paddocks on the farm	18.4	21.0	12.8	22.4	8.6	14.6	4.9	11.1
Stocking rate (AU/ha)	2.9	2.8	1.3	1.5	1.4	1.7	1.3	1.8

NA = Does not apply.

Nicaragua presented the highest adoption in percentile terms (105%), mainly because the extent of improved pastures established on the farms included in the survey in that country was very low. Costa Rica presented the highest rate of adoption in absolute terms (96%), with some 14 hectares of new forage options being planted per farm in addition to the plantings that already existed. In Honduras, although adoption was moderate (28%), this country presented the highest amount of area with improved pastures established per farm (50.8 ha). Furthermore, as in the case of Guatemala, the area under improved pastures was already very high at the onset of the project mostly because of past technology transfer efforts of the national institution, DICTA (Dirección de Ciencia y Tecnología Agropecuaria).

On the other hand, the average number of paddocks per farm significantly increased in all countries, which reflects the good management producers are giving their improved pastures and will allow a better use of available biomass. Similarly, stocking rate increased in all countries, except Guatemala, because in the aftermath of Hurricane Stan, producers were forced to sell their animals to obtain the necessary resources for reestablish lost pastures.

Animal inventory

Table 5 shows the animal inventories per category and country when the project initiated with the corresponding inventories the last year of the project. Except for

Table 5. Animal inventory per category on small dual-purpose farms in Central America.

Parameter	Country							
	Guatemala (n=9)		Honduras (n=16)		Nicaragua (n=16)		Costa Rica (n=15)	
	2003	**2007**	**2003**	**2007**	**2003**	**2007**	**2003**	**2007**
Adult cows	49.1	44.5	30.4	39.6	25.1	33.0	27.1	33.1
Heifers >2 yr	19.7	15.9	13.4	18.6	19.2	24.7	5.1	8.5
Heifers 1-2 yr	9.9	11.1	10.6	15.2	8.5	17.1	4.4	8.6
Female calves 0-1 yr	14.6	10.6	10.4	13.6	7.8	13.3	7.9	12.4
Calves 0-1 yr	13.0	9.4	10.0	12.6	6.8	11.9	8.6	10.4
Young bulls 1-2 yr	8.7	8.1	2.0	4.0	0.8	0.5	2.3	4.1
Young bulls 2 yr	0.0	0.1	1.3	0.0	0.2	0.6	5.0	8.8
Bulls	2.3	2.3	1.6	2.3	1.3	1.8	1.1	1.3
Total animal units (AU)	83.5	74.4	56.8	76.1	49.2	69.5	43.2	58.8
Increase in herd (%)		- 10.9		+ 23.8		+ 41.3		+ 36.1
Mortality (#/yr)	2.6	1.1	4.2	3.2	1.6	1.4	2.1	0.9
Adults	0.7	0.2	2.1	1.4	1.1	0.9	0.9	0.4
Calves	1.9	0.9	2.1	1.8	0.9	0.8	1.2	0.5
Decrease in mortality (%)		- 57.7		- 23.8		- 12.5		- 57.1

Guatemala (where the animal inventory decreased almost 11% due to Hurricane Stan), all countries expanded their herds (between 34% and 41%) in practically all animal categories, not only adult cows. This shows that decision to increase herds is both short- and long-term.

The table also indicates the number of animals that died during each time period and, as can be observed, the adoption of improved forages improved animal diets and, as a result, the number of animals that died decreased, especially during the dry season when nutrient availability and quality are lower. This decrease was very significant in Guatemala and Costa Rica (57%), followed by Honduras (24%) and Nicaragua (12%).

Milk production

Table 6 indicates the milk production of surveyed farms per time of year, at the beginning and at the end of the project. The increase in milk production can be

Table 6. Milk production on small dual-purpose farms in Central America.

Parameter	Time	Year	Country			
			Guatemala (n=9)	Honduras (n=16)	Nicaragua (n=16)	Costa Rica (n=15)
Milking cows (no.)	Dry season	2003	18.1	21.1	17.1	9.6
		2007	17.0	27.4	21.8	13.8
	Rainy season	2003	20.1	21.3	21.0	9.3
		2007	18.9	28.1	25.1	13.6
Daily milk production (l/farm)	Dry season	2003	66.3	104.1	67.4	35.4
		2007	72.4	152.9	98.8	60.7
	Rainy season	2003	108.8	101.3	151.0	51.4
		2007	103.7	149.7	179.7	78.7
Increase in production (%)	Dry season	2007	9.2	46.9	46.6	71.5
	Rainy season	2007	-4.7	47.8	19.0	53.1
Daily milk production (l/cow)	Dry season	2003	3.6	4.9	3.9	3.4
		2007	4.2	5.4	4.4	4.4
	Rainy season	2003	5.6	4.7	6.5	4.8
		2007	5.4	5.2	6.9	5.2
Milk price (US$/l)	Dry season	2003	0.29	0.28	0.29	0.25
		2007	0.39	0.34	0.31	0.34
	Rainy season	2003	0.26	0.22	0.23	0.25
		2007	0.35	0.29	0.24	0.34

attributed to two factors: (a) the increase in the number of milking cows in all countries

attributed to two factors: (a) the increase in the number of milking cows in all countries except Guatemala, where Hurricane Stan forced producers to sell animals to reestablish lost pastures; and (b) the increase in productivity per milking cow during both dry and rainy seasons. On-farm milk production during the dry season increased 9% in Guatemala, 47% in Honduras and Nicaragua, and 71% in Costa Rica. Milk production during the rainy season remained practically invariable in Guatemala, but increased 48% in Honduras, 19% in Nicaragua, and 53% in Costa Rica.

On the other hand, these increases in milk production were also favored by the rise in milk prices in all countries, ranging from 7% in Nicaragua to 36% in Costa Rica during the dry season and from 4% in Nicaragua to 36% in Costa Rica during the rainy season.

Beef production

Table 7 presents beef production, expressed as the body weight at sale of male calves, the number of male calves sold per year, and their age of sale. The age of sale of male calves was similar during both study periods in Guatemala but decreased in the other countries. Calf body weight at sale increased in all countries, although calf age at sale was younger. Similarly, the number of male calves sold per year also increased as a result of larger herds and lower mortality.

Table 7. Beef production on small dual-purpose farms in Central America.

Country	Guatemala (n=9)		Honduras (n=16)		Nicaragua (n=16)		Costa Rica (n=15)	
	2003	**2007**	**2003**	**2007**	**2003**	**2007**	**2003**	**2007**
Age of sale of males (months)	9.3	9.3	8.6	8.4	9.8	9.4	13.0	12.9
Weight of sale of males (kg)	209	218	177	188	141	145	227	254
Males sold per year (no.)	16.6	15.0	9.1	12.5	12.2	13.6	13.4	20.9
Amount of beef sold per year (kg/farm)	3468	3267	1610	2351	1720	1975	3042	5309
Increase in beef production		- 6.0		+ 46.0		+ 14.8		+ 74.5
Sale price (US$/kg live weight)	1.27	1.38	1.12	1.16	1.17	1.23	1.23	1.37

The significant increase in the amount of beef (kg) sold per year at the end of the project, as compared with the amount sold at the beginning of the project, can be attributed to these three factors. Meat production accordingly increased 15% in Nicaragua, 46% in Honduras, and 74% in Costa Rica. similar to the trend observed in milk production, beef production did not increase in Guatemala because producers had to sell animals to recover from the losses caused by Hurricane Stan. Likewise, at the end of the project, producers in all countries received higher prices as compared with those obtained at the beginning of the project. The price of beef paid to the producer increased 9% in Guatemala, 4% in Honduras, 5% in Nicaragua, and 11% in Costa Rica.

Production costs and income

Table 8 lists the annual costs of feed supplements on the surveyed farms and the use of family and hired labor, which accounts for approximately 80% of production costs (Holmann et al., 1992; Holmann, 1993). These costs were accordingly increased by 20% to cover other variable costs.

The table shows that in all countries, except Guatemala, the cost of the supplements used to enhance the basal diet of improved forages increased, which is favorable because feed concentrates and other inputs, when used in small quantities as in this case, proved beneficial because these supplements complement very well the nutrients provided by improved forages (Holmann et al., 2003).

The use of family labor remained stable in all countries, with the same amount being used at the beginning and end of the project. Hired labor, on the other hand, remained constant in Guatemala, decreased slightly in Honduras, but increased in Nicaragua and Costa Rica.

Annual milk production increased in all countries: 6% in Guatemala, 47% in Honduras, 26% in Nicaragua, and a remarkable 157% in Costa Rica. Beef production also increased in all countries, except Guatemala, again because of the reduced animal inventory: 46% in Honduras, 15% in Nicaragua, and 76% in Costa Rica. Farms in Honduras were those that produced the largest amount of milk in absolute terms (55,229 kg/year, equivalent to 151 kg/day) and farms in Costa Rica produced the largest amount of beef in absolute terms (6,145 kg/year).

Table 8. Costs of supplementation and labor, production of milk and meat and gross and net income in farms of small producers of dual purpose in Central America

Parameter	Country							
	Guatemala (n=9)		Honduras (n=16)		Nicaragua (n=16)		Costa Rica (n=15)	
	2003	**2007**	**2003**	**2007**	**2003**	**2007**	**2003**	**2007**
Annual supplementation costs (US$/farm)								
Concentrates	271	262	974	716	220	102	8	55
Molasses	56	18	196	132	132	144	20	88
Hay	0	0	105	87	0	0	77	128
Others	123	66	129	97	129	144	108	221
Subtotal	607	506	1,645	1,306	838	829	213	492
Labor (#)	2.2	2.2	4.9	4.2	2.8	3.6	1.24	1.44
Family members	0.6	0.6	1.6	1.5	1.4	1.4	0.94	0.94
Hired	1.6	1.6	3.3	2.7	1.6	2.3	0.3	0.5
Annual cost of hired labor (US$/farm)	3636	3731	4028	3715	1389	1920	841	1352
Annual milk production (l/farm)	31938	32143	37470	55229	39863	50121	3884	6088
Annual beef production (kg/farm)	4419	4154	1610	2358	1898	2177	3480	6145
Cost per kg milk (US$)[1]	0.12	0.10	0.26	0.15	0.14	0.13	0.42	0.29
Cost per kg beef (US$)[1]	0.86	0.80	1.15	0.62	0.65	0.59	1.38	1.06
Decrease in cost of milk production		16.7		42.3		7.1		31.0
Decrease in cost of beef production		7.0		46.1		9.2		23.2
Annual gross income from sale of milk (US$)	8835	11913	9355	18088	8816	13996	1941	3489
Annual gross income from sale of beef (US$)	4832	4401	1928	2648	2198	2488	3083	5855
Annual net income per farm (US$)	8272	10886	3748	14545	8344	14787	1942	4622
Return to family labor (US$/day)	15.94	32.51	10.11	33.60	18.20	31.44	5.40	13.65
Commercial value of hired labor (US$/day)	5.16	5.29	3.90	3.70	3.17	2.65	8.98	8.67
Returns to labor above commercial value (# times)	3.1	6.0	2.9	9.8	5.5	11.2	0.6	1.8

1. Cost over feeding and labor costs. Family labor is assumed to receive the legal minimum wage. An additional 20% was included to compensate for other costs not included in the survey such as veterinary inputs and others.

Because of these significant increases in annual milk and meat production, major increases were also observed in the annual net income of farms, reaching 32% in Guatemala (despite the reductions in animal inventory due to Hurricane Stan), 288% in Honduras, 177% in Nicaragua, and 238% in Costa Rica. These extraordinary increases in net income can be attributed to three factors: (1) the higher milk price in 2007 as compared with that of 2003; (2) higher production due to the better diet; and (3) increased production due to the higher stocking rate allowed because of the adoption of and increase in area sown to improved forages.

The increase in the net income of these producers has triggered an increase in the economic returns to family labor, as compared with the commercial value of a day's wages. Therefore, the returns to family labor in Guatemala went from 3.1 times the value of the minimum wage in 2003 to 6.0 times that value in 2007, representing a 97% increase. In Honduras, the returns to family labor went from 2.9 times the minimum wage in 2003 to 9.8 times that value in 2007, representing a 238% increase. Similarly, in Nicaragua these returns represented a 104% increase and in Costa Rica a 200% increase.

The adoption of improved forages increased not only the quality of life of small livestock producers by raising their net income, but also the competitiveness of their production systems by significantly reducing the production cost per kg milk and meat. The cost per kg milk decreased 16% in Guatemala, 42% in Honduras, 7% in Nicaragua, and 31% in Costa Rica, and the production cost per kg meat decreased 7% in Guatemala, 46% in Honduras, 9% in Nicaragua, and 23% in Costa Rica.

Conclusions

The adoption of improved forages by the farms participating in the ILRI-led project has resulted in many advantages. Not only has the quality of life of adopting livestock producers improved but communities have also benefited with: (a) the increases in beef and milk production per animal and per unit area, which contribute to a growing food supply for the population with high level of excellent quality proteins; (b) a reduction in the production costs of milk and beef, thus improving the competitiveness of animal production systems of the Central American region; (c) an increase in the use of labor, especially hired, thus generating new employment opportunities; and (d) a significant increase in net income and returns to family labor, thus improving the quality of life of rural livestock producers in Central America.

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References

CIAT 2004. Annual Report 2004. Centro Internacional de Agricultura Tropical. Project IP-5. Tropical Grasses and Legumes: Optimizing genetic diversity for multipurpose use. p. 24-26.

Holmann, F. 1993. Costos de producción de leche y carne, inversión de capital y competitividad en fincas de doble propósito en cinco regiones de Nicaragua. Comisión Nacional de Ganadería, Managua, Nicaragua. 83 p.

Holmann, F.; Argel, P.J.; and Lascano, C.E. 2005. Adoption of *Brachiaria* grasses in Mexico and Central America: A successful story. In: McGilloway, D.A. (ed.). Grassland: A global resource. pp. 343-346. Paper presented at the 20th International Grassland Congress. June 2005. Dublin, Ireland.

Holmann, F.; Estrada, R.D.; Romero, F.; and Villegas, L.E. 1992. Adopción tecnológica y competitividad en fincas de pequeños productores de leche en Costa Rica: Un estudio de caso. Journal of Livestock Research for Rural Development 4(1): 1992. Retreived from http://www.cipav.org.co/lrrd/lrrd4/1/catie1.htm and http://www.cipav.org.co/lrrd/lrrd4/1/catie2.htm

Holmann, F.; Rivas, L.; Argel, P.J.; and Pérez, E. 2004. Impact from the adoption of *Brachiaria* grasses: Central America and Mexico. Journal of Livestock Research for Rural Development (16)12:2004. Retrieved from http://www.cipav.org.co/lrrd/lrrd16/12/holm16098.htm

Holmann, F.; Rivas, L.; Carulla, J.; Rivera, B.; Giraldo, L.A.; Guzmán, S.; Martínez, M.; Medina, A.; and Farrow, A. 2003. Evolution of milk production systems in tropical Latin America and its interrelationship with markets: An analysis of the Colombian case. Journal of Livestock Research for Rural Development (15)9:2003. Retrieved from http://www.cipav.org.co/lrrd/lrrd15/9/holm159.htm